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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 118.

A. C. TRUE, Director.

IRRIGATION FROM BIG THOMPSON RIVER.

BY

JOHN E. FIELD,

Assistant State Engineer of Colorado.

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OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., June 15, 1902.

SIR: I have the honor to submit for publication a report on irrigation from Big Thompson River, Colorado, prepared under the direction of Prof. Elwood Mead, expert in charge of irrigation investigations, by John E. Field, assistant State engineer of that State.

The farmers of northern Colorado have made a more complete use of their water supply than is made in any other part of the United States except California. This development has brought out many interesting features in the practical workings of the Colorado system of water laws. The report deals largely with the legal status of water rights in the Big Thompson Valley, and in the State of Colorado as a whole.

Mr. Field's official connection with water administration in Colorado makes him especially well qualified to discuss this subject. It is through studies of this character that the people of Colorado and of the West can perfect their irrigation systems and secure the highest development of their resources.

It is recommended that this report be published as a bulletin of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INTRODUCTION.

The examination and study of the Big Thompson was undertaken in preference to that of other streams for the reason that it presents many features not found in other districts and at the same time is free from modifying influences and conditions not related to strictly agricultural pursuits or their attendant industries.

The district presents a well-developed and substantial set of local customs and regulations, which appear, moreover, to be sensible and well calculated to produce good results, as evidenced by the considerable length of time they have been in vogue and which have been found to meet the requirements of the people.

That portion of the river on which the head gates are located is not very extensive (Pl. I), and in consequence the matter of regulation of the proper amount of water to be turned into each is much simplified. No great sand bars exist in the river, and its channel is excellent, making the loss of water by evaporation or seepage small.

The art of farming is as well advanced as in any section of the State, and over the entire district there is a notable absence of anything approaching thriftlessness in the methods used. The spirit of orderliness is very apparent in the arrangement of the farm surroundings and in the neatness with which the farms, large and small, are kept up.

There is a great diversity of crops; nearly everything grown in Colorado can be found. Near and just inside the first line of foothills are found thrifty and profitable orchards, and, while most of the farms have more or less of an orchard, those at the base of the mountains are especially noteworthy. Small fruit and garden truck are raised in quantities for the markets. It is the center of the lamb-feeding district, probably 100,000 head being fed on alfalfa each winter, and many cattle also are wintered and fattened here. Wheat, oats, rye, barley, and corn for grain; alfalfa, timothy, clover, and the native grasses of the second bottom as hay, give not only great diversity of farm produce, but of farm labor as well. By intelligent handling the farms are made to produce crops above the general average of the State, and an air of prosperity and energy pervades the community.

There has been a marked tendency toward more intensive farming

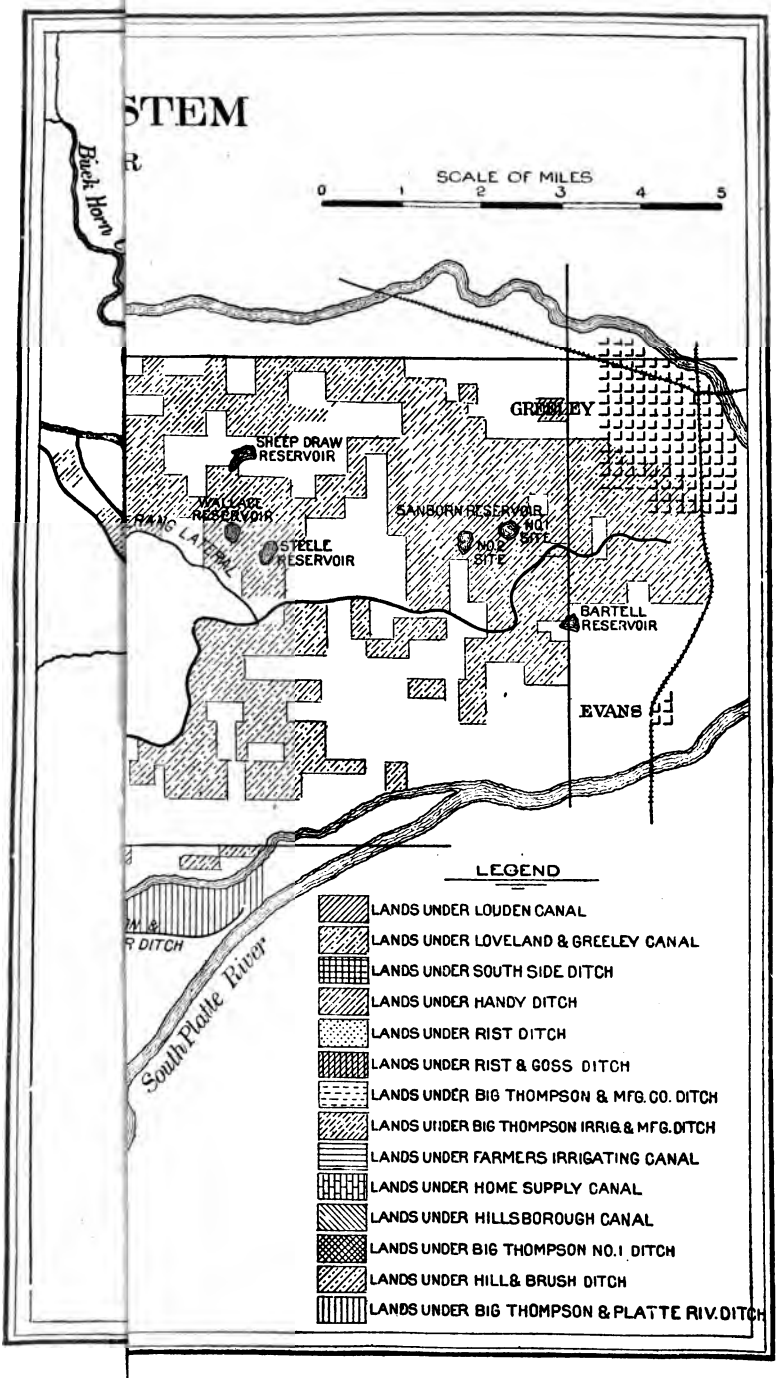
and toward the cutting up of the old and larger farms into smaller tracts of 80 acres and less. This tendency has grown in the last two years, and the land has become more valuable with the prospect for and the building of a beet-sugar factory at the town of Loveland. The year 1901, the first in which beets were extensively planted, has proved the suitability of the soil and climate to the cultivation of this plant.

In the future probably few farms here will exceed 40 acres in extent; every acre will be under cultivation and be made to yield something more nearly approaching the capacity of the land. Indeed, it appears that the district is incapable of increasing its acreage very much, as practically all the land between the ridge on the north, separating the Cache la Poudre and the Big Thompson rivers, and that on the south, separating the Big Thompson and the Little Thompson, is now under ditch and under cultivation. More than this, the water discharged from the canyon is barely equal to the demand. In dry years there is grave apprehension of a shortage of irrigating water, and the utmost economy has to be practiced. Indeed, the very efficient reservoir systems, which will be spoken of later, are the results of the necessity for more and later water.

The storage capacity is almost equal to the excess run-off over and above that needed for direct irrigation. Very little water escapes from the district except in seasons of unusual flow and during short and very heavy storms. In the year 1900 every reservoir in the district was full early in the storing season, which is generally in June, and some water passed into other districts; this, however, was exceptional. During the spring of 1901 many of the reservoirs were practically empty until late in the season; copious rains, however, came, and a good run of water was had, filling the reservoirs to nearly their full capacity, and to the end of the season there was no complaint of the water supply.

Another consideration in selecting the Big Thompson was that its waters are used almost exclusively for agricultural purposes; there is no mining in the district, with its attendant waste and contamination and with its conflicting interests. In some districts of the State the slimes[a] from the stamp mills above, together with the sand and gravel of the placers, cause trouble in keeping the ditches in good condition. The slimes in particular are annoying, as they do not settle readily, and so find their way onto the fields and gardens, where they leave an almost impervious sticky coating of scarcely any fertilizing value, but very deleterious to such fruits and vegetables as come in contact with it. There is likewise no use of water for manufacturing purposes, so that in distribution only agricultural uses are considered.

[a] The technical term applied to the fine powdered rock, mostly in suspension, coming from the stamp mills and closely resembling that carried by glacial streams.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SCALE OF MILES
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Buck Horn
GREELEY
SHEEP DRAW RESERVOIR
WALLACE RESERVOIR
STEELE RESERVOIR
SANBORN RESERVOIR
NO1 SITE
NO2 SITE
BARTELL RESERVOIR
EVANS
LEGEND
LANDS UNDER LOUDEN CANAL
LANDS UNDER LOVELAND & GREELEY CANAL
LANDS UNDER SOUTH SIDE DITCH
LANDS UNDER HANDY DITCH
LANDS UNDER RIST DITCH
LANDS UNDER RIST & GOSS DITCH
LANDS UNDER BIG THOMPSON & MFG. CO. DITCH
LANDS UNDER BIG THOMPSON IRRIG. & MFG. DITCH
LANDS UNDER FARMERS IRRIGATING CANAL
LANDS UNDER HOME SUPPLY CANAL
LANDS UNDER HILLSBOROUGH CANAL
LANDS UNDER BIG THOMPSON NO. 1 DITCH
LANDS UNDER HILL & BRUSH DITCH
LANDS UNDER BIG THOMPSON & PLATTE RIV. DITCH
South Platte River

The district is, moreover, practically independent of others in its claims to water. There is no district above, but below the Big Thompson empties into the Platte River and is subject to the priorities on that stream. However, it is found in practice that the priorities on the Big Thompson are, generally speaking, older than those on the Platte. At such times as there might be a conflict there is an abundance of water. Above the Big Thompson the St. Vrain discharges into the Platte River a reliable flow late in the season, and this, together with a considerable inflow of seepage water, supplies all the old priorities on the Platte below Platteville. The return seepage water in the Big Thompson furnishes all the very old priorities on that stream at its lower end and sends some water into the Platte.

The last, but one of the most important, of the reasons for selecting this stream is that it presents clearly the extreme to which litigation over rights to water may be carried.

PHYSICAL CHARACTERISTICS.

Water district No. 4, or the Thompson district, lies in the South Platte division, or division No. 1, and wholly within the State of Colorado. It embraces portions of Boulder, Larimer, and Weld counties, extending from the continental divide, on the west, eastward to the South Platte River, with elevations varying from 5,000 to 14,000 feet, the entire western boundary being above timber line, which in this latitude is about 11,000 feet. The mountains, especially the northern slopes, are a region blessed with perpetual snow, from which the late water is almost entirely derived. Below timber line the slopes of the mountains are fairly well covered with timber. Fire has not yet caused its entire destruction, and over the burned areas a new growth is spreading rapidly, aiding in the conservation of the water supply by retarding the melting of the snow.

The district may properly be divided into three divisions. The first of these is the mountain region, where both the Little and Big Thompson rivers flow in places through deep ravines and in others traverse open parks of greater or less area. In these parks a few ditches have been taken out for the purpose of irrigating hay meadows. Never far away from the streams, flowing over porous, shallow soil underlaid by solid rock, most of the water soon finds its way back to the river. As these ditches are small and are not included in the adjudication of rights by the court, they are not considered in the distribution of the water of the district, nor will they be considered in this discussion.

The second division includes the lands irrigated by the waters of the Little Thompson. The Little and Big Thompson rivers unite at a point so near the entrance of the Big Thompson to the Platte that the distribution of the water of each is practically independent of the other.

The third division comprises all the land watered by the Big Thompson between the point where it issues from the mountains and its junction with the South Platte River.

In order to confine this discussion within the narrowest possible limits, except in so far as the other divisions may affect the third, that division, by far the most important and the most interesting, alone will be considered.

To one standing on the outer range of foothills near the mouth of the canyon and looking east, the entire valley of the Big Thompson is visible. To the north, extending eastward, is the ridge between the Cache la Poudre and Big Thompson rivers, some 10 miles away at the westerly end, and gradually approaching the river on its eastern trend. The ground sloping gently to the river appears somewhat rolling. To the south a similar ridge marks the boundary between the Little and Big Thompson rivers. Less rolling, the country here presents a smooth, even slope to the river.

The elevation and the fall of the river are such that the higher ditches skirting the foothills soon reach the crests of those ridges and extend down them to the limit of their supply of water for the lower-lying land, but supplying water to lands on both the Cache la Poudre and Little Thompson slopes.

WATER SUPPLY.

Under this head will be found the data collected for a number of years on the subject of precipitation and run-off.

The gauging station on the Big Thompson River was established in 1883 by the late E. S. Nettleton, then State engineer of Colorado, and was located "about 200 yards above the head of the upper ditch, 12 miles from Loveland." This station being found unsatisfactory, was abandoned, and in 1887 another was established about 10 miles west of Loveland and was maintained until 1892. In 1893 and 1894 no readings were taken on the river. On May 9, 1895, a third station was established some 9 miles west of Loveland. Being below both the Handy and Home Supply ditches, a record of both of these, entailing considerable extra labor, was necessary. On this account the station was moved to a point above the head of the Home Supply Ditch April 1, 1899. This station, located about 3 miles south of the post-office at Arkins, at a point where the wagon bridge crosses the stream, though below the Handy Ditch, is quite satisfactory. The gauge rod is a vertical 2-by-4 fastened on the downstream side of the south abutment of the bridge.

The channel, though quite rough and full of bowlders, is permanent, and the results obtained are reliable. The entire record for the river at the several stations is given in the accompanying table:

Comparative table of discharge of Big Thompson River at Arkins, Colo.

Month.	1888.	1889.	1890.	1891.	1892.	1895.	1896.	1897.	1898.	1899.	1900.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
April:											
Maximum	110.	.....	.....	.....	.....	.....	74	.....	.....	331	1,990
Mean	62	.....	.....	.....	.....	.....	37	.....	.....	140	412
Minimum	10	.....	.....	.....	.....	.....	5	.....	.....	4	4
May:											
Maximum	260	546	707	.....	482	420	911	666	341	510	2,090
Mean	132	359	436	.....	312	318	218	420	164	303	1,382
Minimum	50	130	225	.....	195	217	5	64	13	146	895
June:											
Maximum	760	527	712	1,182	1,195	823	483	850	605	1,685	1,990
Mean	458	382	530	817	704	570	285	465	377	917	1,362
Minimum	200	208	365	523	329	344	180	36	85	451	737
July:											
Maximum	410	370	1,603	634	864	778	403	459	517	1,189	556
Mean	275	200	454	383	498	465	225	267	238	653	349
Minimum	160	108	255	219	259	293	152	146	85	416	208
August:											
Maximum	580	137	643	235	247	696	443	390	177	589	208
Mean	190	89	393	159	150	319	144	133	79	283	137
Minimum	100	53	185	105	81	174	38	36	45	146	88
September:											
Maximum	180	59	235	137	90	217	195	85	98	146	88
Mean	75	49	151	95	49	146	119	37	36	92	77
Minimum	60	40	65	69	39	32	74	15	8	35	60
October:											
Maximum	100	50	97	.....	.....	132	138	48	24	[a]116	.....
Mean	46	46	67	.....	.....	79	66	17	13	64	.....
Minimum	40	28	51	.....	.....	20	20	5	4	35	.....
November:											
Maximum	.....	.....	100	.....	.....	.....	.....	64	24	.....	.....
Mean	.....	.....	83	.....	.....	.....	.....	27	8	.....	.....
Minimum	.....	.....	60	.....	.....	.....	.....	5	4	.....	.....

[a] No record October 1 to 7.

On account of the uncertainty of the location of the earlier stations and because it is not known whether the waters diverted by the ditches above the stations were included in the discharges as given, the records for the years 1888 to 1892, inclusive, have been excluded in making estimates of the discharge and run-off. In the table which follows the volume diverted by the ditches is added to the discharge as given in the preceding table, and the average computed for the six years 1895 to 1900, inclusive.

Run-off of Big Thompson drainage area.

Month.	1895.	1896.	1897.	1898.	1899.	1900.	Average.	Average monthly precipitation.[a]
	Cubic feet per sec.	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Inches.*
January	[b]60	[b]60	[b]60	[b]60	[b]60	[b]60	60	0.71
February	[b]60	[b]60	[b]60	[b]60	[b]60	[b]60	60	1.49
March	[b]100	[b]100	[b]100	[b]100	[b]100	[b]100	100	1.75
April	[b]250	37	[b]250	[b]250	302	412	250	2.19
May	440	269	590	231	353	1,382	544	2.60
June	931	363	679	498	1,037	1,497	834	1.18
July	687	261	379	317	770	379	465	2.27
August	426	173	196	112	316	159	230	1.74
September	185	161	71	57	103	87	111	1.07
October	116	97	54	23	64	[b]71	71	1.11
November	[b]70	[b]70	27	17	[b]70	[b]70	54	.69
December	[b]60	[b]60	[b]60	[b]60	[b]60	[b]60	60	.68
Average	282	143	211	149	275	361	237	17.48

[a] Melted snow and rain. [b] Estimated.

Comparative statement of run-off and precipitation.

Year.	Precipitation.	Precipitation.[a]	Run-off.	Run-off.
	Inches.	*Inches.*	*Inches.*	*Per cent.*
1895	22.37	24.10	12.5	52
1896	17.28	17.07	6.3	37
1897	18.87	17.02	9.3	55
1898	16.86	16.99	6.6	39
1899	16.58	18.25	12.1	66
1900	16.72	16.42	16.0	97

[a] Year ending October 31.

It was found necessary to estimate the discharges for the months when no record was kept. These, being the months of least flow, were easily determined. At the same time any error in the estimate affects the general result but little. In arriving at the conclusions given the discharges of other rivers in the State which had records covering the entire year were examined. As a result of such examination the general proposition may be stated that streams reach their minimum before the 1st of November, increasing thereafter slightly to December, and thereafter the discharge is quite constant until the warm days in spring increase the flow.

The following tables of precipitation are furnished by the United States Weather Bureau and are for the three stations of the district. The Longs Peak and Moraine stations are located well back in the mountains, the Moraine station having an elevation of 7,900 feet above sea level. This station, located on one of the branches which constitute the headwaters of the Big Thompson, is about 6 miles from the summit of the range, and, being so situated, gives a much better general average of rainfall on the watershed of the Big Thompson than either the Longs Peak station or the Waterdale station. Besides this, the observations cover nearly twice as many years. For these reasons, in estimating the run-off relative to the precipitation, the averages in this table have been used. The Waterdale station is located near Arkins, just inside the first range of low foothills, and these records are of most use in cases where the precipitation on the cultivated land is wanted.

Precipitation for Longs Peak station, Larimer County, Colo.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1895	.....	.....	.....	.....	.....	2.70	4.61	1.52	1.10	2.60	0.50	0.17	.....
1896	0.26	0.55	3.17	1.00	1.21	.65	3.60	2.95	1.95	1.05	.37	.15	16.91
1897	.78	1.25	1.96	1.45	1.60	1.50	1.85	1.29	.95	1.41	1.07	.55	15.66
1898	.24	.83	.75	1.73	2.07	2.06	2.94	1.53	.81	.60	1.60	.60	15.76
1899	.54	1.15	3.01	1.18	.38	1.09	4.32	1.73	.11	2.50	.02	.64	16.67
1900	.16	.85	.35	6.34	.60	.80	.51	.17	1.93	1.14	.44	.64	13.93
Mean	.40	.93	1.85	2.54	1.17	1.47	2.97	1.53	1.14	1.55	.67	.46	16.48

Precipitation at Moraine station, Larimer County, Colo.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1889....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.57	0.40	0.64	.....
1890....	0.81	0.76	0.71	2.77	1.30	1.05	2.42	3.40	0.82	1.34	.65	.35	16.38
1891....	2.38	3.00	3.52	1.80	3.26	1.10	1.12	.99	1.45	.31	.94	.92	20.79
1892....	.50	1.30	1.34	1.69	3.21	.84	2.17	.62	.06	.55	.60	.60	13.48
1893....	.69	2.32	1.88	1.34	1.76	.37	1.43	1.83	.21	.43	1.03	.90	14.19
1894....	.40	.99	1.08	1.86	5.72	.38	2.25	1.26	2.13	.56	.54	1.58	18.75
1895....	.42	1.60	1.40	1.74	4.63	2.53	3.66	2.86	.84	2.30	.35	.04	22.37
1896....	.53	.22	2.87	1.08	1.62	.49	3.88	2.50	2.74	.75	.30	.30	17.28
1897....	.61	1.68	1.86	1.29	2.30	1.79	2.52	2.43	.78	1.16	1.25	1.20	18.87
1898....	.50	1.05	1.32	1.44	3.05	1.93	2.19	1.67	.40	.99	1.77	.55	16.86
1899....	.77	2.32	2.98	1.39	.45	1.57	3.02	1.32	.15	1.96	.00	.65	16.58
1900....	.21	1.11	.30	7.74	1.30	.91	.36	.23	2.19	1.42	.47	.48	16.72
Mean	.71	1.67	1.75	2.19	2.60	1.18	2.27	1.74	1.07	1.11	.69	.68	17.48

Precipitation at Waterdale station, near Arkins, Colo.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1895....	0.21	1.33	0.98	1.89	4.95	4.60	5.84	0.57	0.51	1.15	.....	.....	.....
1896....	.62	.28	1.50	1.22	1.66	1.83	2.58	1.44	2.60	.68	0.08	0.43	14.92
1897....	.18	.50	2.32	1.82	3.61	2.30	2.42	1.09	.84	1.07	.82	.64	17.61
1898....	.24	.25	.87	1.42	3.43	1.86	1.20	1.61	.51	.75	1.62	.50	14.26
1899....	.63	1.10	1.25	.84	.67	.92	2.12	.94	.19	3.30	.00	.49	12.45
1900....	.19	.86	.97	9.21	1.76	.45	1.05	.57	1.72	.18	.12	.22	17.30
Mean	.34	.72	1.32	2.73	2.68	1.99	2.54	1.04	1.06	1.19	.53	.46	16.60

A comparison of the averages of the three tables shows that the rainfall is very evenly distributed, there being little difference between that of places at an elevation of 6,000 feet and of those at 9,000 feet. Nor does there appear in the tables anything to indicate that the precipitation is differently distributed over the year, all three showing the least precipitation in winter and the most in the spring and summer. The records cover a period scarcely long enough to make comparisons or to reach conclusions. An attempt was made to ascertain what relation the precipitation during the winter had to the late flow of the river, but no conclusion was reached while considering chiefly the snowfall at the high altitudes. In this study the year was divided not at January 1, but at November 1, assuming that the snow falling after November 1 would remain until spring at least. This failure to reach a conclusion is not surprising, for the late flow is dependent as much upon the amount of drifting as upon the quantity of snowfall, it being only deep drifts that remain late. The temperature in spring is a factor, as is also the rainfall at that time. Warm spring rains melt the great drifts on the northern slopes and in the sheltered places rapidly. The rain, augmented by the melted snow, flows away almost immediately, while snow melted by the sun late in the day refreezes to a considerable extent the succeeding night. The slower melting of the snow also allows the water to enter the soil and the cracks and crevices of the rocks, to reappear later in the season in springs which

feed the river. This applies to the untimbered portions and those above timber line where the winds and rains have free access to the snow, and has especial reference to Longs Peak station. Under these modifying conditions, of which there are no records and which inject so many variables into the calculation, and with so few years of complete records to consider, even though conclusions were reached, they would not be positive in their character. Necessarily a good snowfall during the early winter on the higher elevations melts later than that lower down when unprotected under similar conditions of rain and sun during the melting period. If the winds aid in building deep drifts in the ravines, or if there are no warm rains, the beneficial result of an early snow is quite marked. The records given here, however, seem to indicate that the run-off from protected snows can be more easily predicted in advance and are less affected by the conditions of rain, sun, and wind during the melting period.

The run-off and average rainfall, as given above, seem to bear a relation to each other. Both being considered for the year, one would expect little difference in their relative proportions. By the table, the year 1895 had 22.37 inches precipitation and an average run-off of 282 cubic feet per second. The following year a decrease in rainfall brought a decrease in the run-off of 139 cubic feet per second, nearly 50 per cent. In 1897 there was an increase in both items, in 1898 a decrease in both, while for 1899 the run-off was nearly twice as much as in 1898, and in 1900 nearly three times as much as in 1898, with scarcely any difference in precipitation for the three years. The run-off for the year 1900 exceeded, indeed, that for 1895, with its record-breaking rainfall of 22.37 inches. The difference of time of year of the rainfall and the run-off for these years of extremes will now be examined. In 1895 it is seen that the run-off had a maximum recorded discharge of 931 cubic feet per second and a minimum of 116 cubic feet per second; that for August, September, and October, months of small discharge, the flow exceeded that of any other year for the corresponding months. For May, June, and July, however, the average run-off for 1895 is exceeded a number of times in years greatly less in total precipitation, as, for example, May, 1897, June and July, 1899, and May and June, 1900. The year 1900 is especially remarkable, May and June showing the highest run-off for any months of which there is record, while for the months of small flow the discharge is considerably below the normal. Turning now to the record of precipitation, it will be seen that at the Moraine station it was remarkably well distributed throughout the different months of 1895, with a maximum for May of 4.63 inches, about one-fifth of the total. In 1900, however, the distribution was very poor, 7.74 inches falling in the month of April alone, almost one-half of the rainfall for the entire year. Although the total run-off for 1900 was far in excess of

that for 1895, much of the water escaped and was not available for irrigation. Neither the reservoir nor the feeder-ditch capacity was sufficient to store more than a fraction of the flow for May and June, nor would it be economy to increase them to an extent sufficient to store such floods, occurring as they do at rare intervals; in fact, only once in twelve years is such a flood recorded. Therefore a uniformly distributed rainfall, as in 1895, even though it give a much smaller percentage of run-off as compared with precipitation, is better than that of a year like 1900, when most of it occurs in a short period.

The variations in the percentages of run-off and its causes will now be considered. The run-off for 1895 was 52 per cent, while that of 1900 was 97 per cent of the precipitation. The great loss of 1895 was caused by the long exposure to the dry winds, a large amount of even the early winter snows passing directly from the solid to the vaporous state. The remarkable run-off of 1900 is due principally to the rapidity with which the water reached the stream and to the short exposure. Two other causes, which might be classed as errors in the data used, contributed to swell the percentage of run-off: First, the precipitation on the lower reaches of the river, as shown by the Arkins station records, was greater than that shown by Moraine station records; second, almost no old snow remained after the summer of 1900. Snow banks which had been considered "perpetual" had by the action of the rains been almost entirely melted. This snow, deposited in previous years, of course does not appear in the records of precipitation for the year 1900. Considering the long exposure of 1895, the percentage of loss by evaporation is not remarkable. In the year 1899 there was a large precipitation in the early spring, probably in the form of light snow, which, melting rapidly as the weather warmed, caused high water in the early summer. The bountiful snowfall of the preceding November and December furnished a good late flow.

The record of Longs Peak station failed to establish a relation between a late flow and the snowfall in the early winter; but here we have, when considering the precipitation for lower altitudes, apparently positive proof that early winter snows do augment the flow. What, then, is the reason for the apparent slower run-off at the lower altitudes? As already mentioned, the timber near the headwaters is still well preserved and new timber is coming up where fire passed some years ago. In these lower altitudes the soil is deeper, the many small depressions form lakes and marshes, and numerous small grassy parks are found; all these aid in retarding the escape of the water. A good fall of snow in the spring will lie in the timber for a long time; such as falls on the little open parks is absorbed by the ground as it melts; the melting in the timber is slow and almost all the water sinks into the ground, and, while the snow itself may disappear early, con-

siderable time is consumed by the water in percolating through the soil before it appears again in the springs and water courses lower down.

The forests, especially, aid in holding back the water, for they protect both the unmelted snow and the wet ground or surface water from the dry winds and sun, and the loose, porous soil of the forests will absorb water almost as fast as the snow is melted. In the higher unforested areas, the ground being much steeper and with less covering to absorb the melted snow, the run-off is much more rapid.

From the above the following statements are formulated:

(1) Snows in the early winter in high altitude will furnish a late flow, but the amount of late flow therefrom is modified at first by the drifting and then by weather conditions as regards rains and cloudiness.

(2) Snows in the forested areas give a better distribution of run-off than in unforested areas.

(3) Years of well-distributed precipitation give a more even and later flow in the rivers than years of excessive periodical rains; but years of evenly distributed rainfall give a less total of run-off.

The average run-off for six years was 237 cubic feet per second for the entire year. This means a total of 470 acre-feet per day, or 171,550 acre-feet per year.

The drainage area of the Big Thompson above the gauging station is given as 305 square miles, or 195,200 acres. The run-off in depth over the entire surface is therefore 0.88 foot, or 10.56 inches, as compared with 17.48 inches precipitation. This indicates that about 57 per cent of the total precipitation would be available for irrigation if it could all be stored or should come at such time and in such volume as could be used for direct irrigation. This subject will be treated in the discussion of duty of water and reservoirs.

DITCHES.

In the valley of the Big Thompson prior to 1861 there was very little settlement, the gold excitement being much farther south, the point farthest north where any mining was done being on Boulder Creek.

It was the mines that furnished, in the earliest days as they do now, the best and most profitable market; and then, as now, the farms made possible the development of most of the mining resources.

The irrigation of the meadow lands required a great deal of water, or, if they did not really require it, it took a great deal to injure them. Underlaid, as they usually were, with a bed of coarse gravel, bowlders, and wash, they drained quickly, and little alkali was brought to the surface, that undesirable substance coming later from the upper lands. The higher grounds were leached by the excessive application of water;

the resultant seepage, strongly impregnated, appeared later in the lower lands, and, evaporating, left on the surface a coating of white alkali.

In the construction of the earlier ditches no attempt was made to reach a level higher than the bottom lands. The early settler was skeptical as to the ability of the upper lands to produce anything other than short grass and cactus, and the running of ditches out onto the mesas was too great an undertaking. The ditches began only high enough up on the stream to cover the land of the builders, and were given a grade more with reference to making the water run than to maintaining a maximum elevation. The matter of erosion of the ditch was never considered. The ditch was carried over the edge of the first mesa and thence along its foot on no uniform or fixed grade. Often the rate of fall was greater than that of the river itself, which in its meanderings back and forth traversed much longer distances than the ditch between the same points. The consequence was that the ditches washed and grew larger and larger. An extension required no enlargement of the old portion, and the abundance of water and the ease with which a large amount was obtained led to excessive use. If the decrees were based on the sizes of the ditches it is not surprising that they were excessive.

There were probably earlier, small, unimportant, and now forgotten ditches, but at present there are only 15 in all. Of these, 2 are practically abandoned and 2 are small and supplied by seepage, while 1 other has no decree and is likewise supplied by seepage. Those ditches which survived up to the granting of decrees in 1881 are described below, and, as far as possible, their original names, locations, sizes, and the land covered at the various periods are given. It is a delicate matter to make statements concerning these ditches, in view of the lawsuits past and anticipated. When voluminous court records give directly conflicting evidence by the "oldest inhabitants," one will surely be excused for so often using the words "possible," "probable," "perhaps," and "about."

The statement of the former and present value of lands under several ditches is given for three reasons:

(1) To compare them with unirrigated Government and railroad lands.

(2) To show the change of sentiment toward bottom lands and those on the mesa. In the early days bottom lands only were of much value, yet a few years ago they were the lowest priced of any in the district. The reclamation of this land by drainage will make it very valuable for the planting of onions in particular and of sugar beets, as it is very rich though hard to thoroughly subdue. It is quite rough and requires leveling to make it available for these crops.

(3) These lands are certain to again be of great value, and it is for future comparison also that the data is given here.[a]

THE BIG THOMPSON DITCH.

A description and a history of the construction and management of this the first ditch upon the Big Thompson of which there is any record or which is of importance at the present time, is similar to that of all the early ditches in the district, and much of what is said will apply as well to other districts throughout the State. According to the record the survey and construction were begun November 10, 1861, the ditch being a neighborhood enterprise intended to water the lands of a number of adjoining farms.

Without irrigation the grasses of the meadow lands were generally forced to maturity by the hot weather and the want of moisture before the growing season was really over, and the product was light, although making an excellent feed. The experiment having been tried in other communities with good results, it was believed that the application of water would very materially lengthen the growing season and produce a much greater tonnage. So we see that ditch building was almost coincident with settlement.

The Big Thompson Ditch was some 8 miles long, covering a narrow strip of land, seldom more than a mile in width along the river bottom, and amounting probably to less than 3,000 acres, being almost entirely hay land of the second bottom. The decree gives the ditch 96.5 cubic feet of water per second, which purports to be the amount actually carried at times by the ditch and necessary for the land watered. While it is possible that the ditch had a capacity equal to the decree and possibly did at times carry that amount, it is hardly credible that that quantity was either necessary or carried for any considerable time.

In 1897 28 cubic feet of water per second was transferred by order of the district court to the Hillsboro Ditch. This transfer served two purposes: (1) A consolidation of interests with a consequent decrease of expense in maintenance, and (2) it made possible the irrigation of higher and better land. Such a transfer could hardly be objected to by outside parties, as the head gate of the Hillsboro Ditch is but a mile above that of the Big Thompson, and any seepage water previously used was still available, and if the full appropriation had formerly been diverted to irrigate the bottom lands its use on the more valuable upland, requiring less water, was certainly wise. In 1897 the superintendent of irrigation made transfers of individual shares to the Hillsboro Ditch as follows: Two of 14, one of 7, and two of 5 cubic feet per second each. In the same year two shares of

[a] The prices given were obtained in 1901 and have already very materially changed.

5 cubic feet per second each were transferred in similar manner to the Home Supply Ditch. Permission was also given to transfer one of 7 cubic feet per second to the Loudon Ditch. This transfer, however, is uncertain, as the interests of the Loudon Ditch appear to demand a prohibition of transfers of all kinds, and it is probable that this company will resist the other transfers permitted by the superintendent of irrigation. There now remains in the Big Thompson Ditch 5½ cubic feet of water per second, irrigating some 500 acres, with a possibility of the return of 62 cubic feet of water per second temporarily transferred to other canals. This ditch in its present condition can not carry to exceed 25 cubic feet per second. It in all probability had been in that condition for a considerable time prior to the transfers of water. From data at hand the ditch carried but 22 cubic feet per second in 1890 and covered but 640 acres of land. The value of land under this ditch in the early days was from $40 to $60 per acre; its value now, however, is about $20 per acre. The decrease is easily accounted for in the decline in the price of wild hay from $50 or $100 to less than $10 per ton, together with the fact that much of the land has become water-logged.

MARIANO DITCH.

The ditch, designated as priority No. 3, was built in 1862 by a Mexican by the name of Mariano and his people, to irrigate lands on the south side of the river. The ditch was small, and Mariano, unable to cope with American energy in the acquirement and perfection of water rights and the holding of land, at length found himself confined to some 40 acres. The ditch was gradually abandoned and is now a record only. This was the first private ditch in the district. At the time of the decree its owners claimed for it a capacity of 38.4 cubic feet per second; however, as they testified that it irrigated but 120 acres, and although the referee stated that there was insufficient data for granting a decree, the court granted 3.12 cubic feet per second, or an inch (0.026 cubic foot per second) to the acre.

THE BIG THOMPSON AND MANUFACTURING COMPANY'S DITCH.

This ditch is located on the south side of the Big Thompson, about 2 miles west of Loveland. It is less than 7 miles in length, covers about 1,300 acres on the river bottom, and was the first ditch in the district to incorporate. Its first decree of 34.02 cubic feet per second is dated April 1, 1863. The ditch was enlarged and extended in 1864, acquiring its second right of 37.01 cubic feet per second May 1, 1864. In 1867 the head gate was moved farther up the river and the ditch built to cover land farther back from the river. Being much larger than the

old ditch, it acquired its third right of 65.47 cubic feet per second. In May, 1872, it claimed a fourth appropriation of 9.75 cubic feet per second, making a total of 146.25 cubic feet per second. From the present size of the ditch, its location, and the amount of land covered, it does not seem possible that more than 75 cubic feet per second was ever carried, and at present it does not run to exceed 25 cubic feet per second. Some ten years ago, by measurement, it had a maximum capacity of not to exceed 50 cubic feet per second. In the application of the claimants for a decree the maximum amount of land claimed to have been irrigated was but 1,500 acres, while the land susceptible of irrigation was but 2,180 acres. According to the referee the capacity of the ditch was 213 cubic feet per second, with a fall of 25 feet to the mile—considerable water for such a fall; the court, however, granted but 146.25 cubic feet per second for the 2,180 acres, something over 2½ inches to the acre, or, for the 1,500 acres irrigated a duty of something like 10 acres to the cubic foot per second. Under the same ditch on the same land the duty at present is about 162 acres to the cubic foot per second.

Attention is called here to the table under the heading "Titles to water," page 64, which gives a summary of the findings of the court on all the ditches.

Transfers have been made as follows:

To the Home Supply Company, by sale, 24 cubic feet per second; by permission of the superintendent of irrigation, 22 cubic feet per second for five individuals, the amounts being 10, 4, 3, 3, and 2 cubic feet per second.

To the Handy Ditch, 6 cubic feet per second, by permission.

To the South Side Ditch, 6 cubic feet per second, by permission.

To the Farmers' Ditch, 1½ cubic feet per second, by order of the court.

To the Loudon Ditch, 1 cubic foot per second, by permission.

Against this transfer, however, the Loudon company will protest. If the estimate of 75 cubic feet per second maximum capacity is correct, and if the transfers stand, but 3.97 cubic feet per second remain of the water used before the transfers for this ditch. In making the sale to the Home Supply Ditch the part sold was not all of one priority, a proportionate amount of each of the four appropriations, approximately one-sixth of each, being sold. The value of this water in the Home Supply Canal averages probably $1,000 per cubic foot per second, while the price paid is said to have been $400 per cubic foot per second. The land being much the same as under the Big Thompson, has, as a whole, decreased in value; some of the land, however, is excellent and worth probably $50 per acre.

There are no reservoirs or reservoir sites under this ditch.

THE FARMERS' IRRIGATING DITCH.

By successive enlargements this ditch has the following rights:

Decreed rights of Farmers' Irrigating Ditch.

	Cubic feet per second.
May 1, 1864	5.72
June 1, 1868	2.60
August 1, 1878	54.08
Total	62.40

It is located just south of Loveland on the north bank of the river; it is about 9 miles in length and covers 4,500 acres of land worth $45 per acre. The area irrigated is probably nearly 3,000 acres. It has 30 shares, of a value of $1,200 each; each share supposed to be sufficient for 160 acres. This ditch carries 1½ cubic feet of water per second, decreed to the Big Thompson and Manufacturing Company's Ditch by order of the district court. Had the amount been larger the transfer would probably have been resisted by other ditches injuriously affected.

The annual expenses on the ditch average for superintendence $300 and for repairs $300.

The capacity at present is about equal to its decreed rights.

There are no reservoirs or reservoir sites under this ditch. Considering the amount of water allowed per acre cultivated for the Big Thompson and Manufacturing Company's Ditch, the amount of water decreed this ditch seems to be very small. Although this ditch was actually irrigating one-third more land and had under it twice as much land as the manufacturing company's ditch, its decree is less than one-half as large. Though the character of the land under each is similar, the court saw no inconsistency in its decrees.

THE BIG THOMPSON IRRIGATING DITCH.

Having priority No. 5 in the district, this ditch is locally designated as "No. 5 ditch." It is some 5 miles long and covers about 1,000 acres of land along the river bottom.

Considerable controversy has arisen over the decrees of this ditch and its capacity in connection with its sale to the Handy Ditch Company.

The head of the ditch was located some 2 miles southeast of Loveland, and since 1895 has not been used. The decree is for 78 cubic feet per second, of date of February 25, 1865, which the Handy Ditch Company purchased in 1897, together with the land covered by the ditch. Upon application to the superintendent of irrigation in 1897 to transfer the full 78 cubic feet per second he allowed 40 cubic feet per second to be changed, provided the old ditch be abandoned. On

appeal to the State engineer that official caused the line of the old ditch to be carefully surveyed and its cross section determined. The result of the survey showed that the ditch could carry more than 78 cubic feet per second, even taking the least cross section and lightest grade found as a basis of calculation. The State engineer, therefore, ordered the entire decree to be transferred, which resulted in suit being brought, under the the title of "The Loudon Irrigating Canal Co. *v.* the Handy Ditch Co. et al." This case is given more fully later. At present the Handy Ditch is allowed to draw not more than 20 cubic feet per second of this water. In obtaining a decree the capacity as claimed by the owners was but 75 cubic feet per second, but notwithstanding this the decree grants 78 feet per second, or 3 "inches" of water per acre. The size of the ditch is given as 8 feet on the bottom, 14 feet on top, 3 miles in length, 2½ feet in depth, with a fall of 10 feet to the mile.

THE LOVELAND AND GREELEY CANAL.

The canal or, rather, system of canals and reservoirs which goes under this name is one of the most important in the district, extending, as it does, from a point on the Big Thompson some 3 miles west of Loveland nearly to the town of Greeley, supplying water along its entire course to more than 21,000 acres, the greater part of which lies near Greeley and on both the Big Thompson and Cache la Poudre slopes. The name Loveland and Greeley was applied to the main canal as it was enlarged. The head gate is located in sec. 17, T. 5 N., R. 69 W., and the system embraces the old Larimer County Irrigating and Manufacturing Ditch, commonly called the Chubbuck Ditch, with its priorities as follows:

Decreed rights of Chubbuck Ditch.

	Cubic feet per second.
November 1, 1865	8.36
October 20, 1870	39.04
October 25, 1873	35.50
Total	82.90

This total of 82.90 cubic feet per second, added to the decree of April 1, 1881, of 297.44, makes a total of 380.34 cubic feet per second. With this latter enlargement (the extension of the canal by the Boomerang and Grapevine laterals) it covered some 30,000 acres. The old Larimer County Irrigating and Manufacturing Ditch at the time of its decree covered about 2,100 acres, of which 1,800 were irrigated. In acquiring this ditch the Loveland and Greeley Irrigating and Land Company guaranteed to the owners thereof a perpetual free and first right to the water of the canal at such times as it was needed and in amount to the full extent of their priorities. The company does not, however, furnish reservoir water under this agreement. The amount

of land so irrigated amounts to about 3,100 acres, and the amount of free water furnished is 1,815 inches under a 2-inch pressure.

The Barnes Ditch was another acquirement by the company under similar agreement, the company furnishing free water to the extent of 2,100 statutory inches. The land watered, however, scarcely exceeds 1,000 acres. The Barnes Ditch had four priorities, as follows:

Decreed rights of Barnes Ditch.

	Cubic feet per second.
October 20, 1865	18.56
June 1, 1867	12.06
June 23, 1873	19.93
November 1, 1878	15.20
Total	65.75

The ditch was acquired and enlarged as a feeder to Lake Loveland, and when in good repair has a capacity of more than 400 cubic feet per second. The total decreed right of the Loveland and Greeley Canal is 446.09 cubic feet per second.

Four kinds of rights exist under this system—the old Larimer County Irrigation and Manufacturing Ditch free rights, the old Barnes Ditch free rights, the rights under the Loveland and Greeley Canal proper, and the Lake Loveland Reservoir rights. A piece of land may have a reservoir right with either of the others, or a reservoir right alone. There are 208 rights of 80 acres each under the Loveland and Greeley Canal proper, of which 205 are in use; under the reservoir are 300 rights of 80 acres each, of which 175 are in use. There is considerable land covered by no water right that lies under the ditch and the reservoir whose outlet is the ditch, and it is probable that some of this land is watered. A water right, being about 1.44 cubic feet per second, is made to cover much more than 80 acres, the waste and seepage water being used.

The range of value of the land is considerable, but $75 per acre is not uncommon even for 160-acre tracts, especially if it possesses both ditch and reservoir rights.

THE BIG THOMPSON AND PLATTE RIVER DITCH.

This ditch is located at the extreme lower end of the district, just above the mouth of the Little Thompson, from which it draws some seepage water. It has two priorities, one dated November 18, 1865, for 35 cubic feet per second, and one dated May 15, 1876, for 86.18 cubic feet per second. Its first priority is supplied principally from seepage. The ditch covers about 1,800 acres between the Big Thompson and the Platte River, and has a carrying capacity of about 40 cubic feet per second. The cost of maintenance, including supervision, is about $500 per year. This ditch is a source of very little trouble to

the commissioner, he having to visit it seldom, as there is generally enough seepage to supply its needs when water is scarce.

RIST AND GOSS DITCH.

This is a small ditch on the south side of the river, and is used to irrigate portions of two farms, that of Mr. Percy D. Goss and of the Buckingham estate, in all about 300 acres. Its capacity at present is about 20 cubic feet per second, and it is some 2 miles long. Its priorities are, March 20, 1866, 6.41 cubic feet per second, and April 15, 1875, 80.07 cubic feet per second. According to the findings of the referee, but 400 acres were covered by both appropriations, and but 225 acres actually irrigated, while the amount actually appropriated was 4.68 cubic feet per second. A third enlargement was claimed, but not allowed. Also, according to the findings, the land requires 0.0208 cubic foot per second per acre, or a total of 8.32 cubic feet per second, but in the face of this the court grants 86.48 cubic feet per second, more than ten times what was apparently recommended by the referee. There are no reservoirs under this ditch, but the decree seems to be ample without one.

HILL AND BRUSH DITCH.

This is a small private ditch on the north side of the river, near the lower end of the district. It is about 5 miles long, and has a maximum capacity of 15 cubic feet per second, but a decree of 61.8 cubic feet per second. The referee says as this ditch covered 1,500 acres, and required 0.0208 cubic foot per second per acre it had acquired a right to 31.2 cubic feet per second "by construction," though its owners claimed for it 69 cubic feet per second. The court, disregarding the findings and recommendations of the referee, gave the ditch a decree of 61.8 cubic feet per second.

THE LOUDON DITCH.

The Loudon Ditch is the highest on the stream on the north side, waters land on the Cache la Poudre slope, and is one of the most important in the district. It has good and large priorities, but, having no reservoirs, is short on late water. There are a few private reservoirs, and some good sites which might be utilized. It is some 26 miles in length, counting its more important laterals, irrigates more than 10,000 acres, and covers about 13,000 acres. Its capacity is equal to its first two decrees. This ditch originally covered 400 acres, of which one-half was irrigated. The referee says that the capacity of this old ditch was 21.19 cubic feet per second, but that 40 cubic feet per second were claimed, and it was so allowed. The canal has two later appropriations—154.3 cubic feet per second November 1, 1877, and 123.48 cubic feet per second September 17, 1883. It is carrying at present 9 cubic feet per second of transferred water; 8 cubic feet per

second from the Big Thompson No. 1 and 1 cubic foot per second from the Big Thompson and Manufacturing Company's Ditch. However, the management deny that they recognize the transfers. Land under this ditch is valued at $60 per acre.

THE GEORGE RIST DITCH.

The ditch is used to irrigate land belonging to the Buckingham estate only, about 1,800 acres, and has a capacity of 66 cubic feet per second. Formerly its capacity was less than half that amount, but when the Mariano Lake was put to use by the Home Supply Ditch Company, it purchased a right of way through this ditch, enlarging it and making it a feeder for the lake. Besides a money consideration for the right of way, the company assumes the cost of maintenance for its use. The ditch has one decree only, of 195 cubic feet per second, of date May 1, 1873, though application for decree was made under two dates—May 1, 1873, and July 9, 1875. There had been actually irrigated in the first case but 100 acres, and in the second 2,400 acres.

HILLSBORO DITCH.

This is the most important of the lower ditches, as well as one of the largest in the district. It extends from a point on the south bank of the Big Thompson, some 5 miles below Loveland, in a curve around to and across the Little Thompson, and irrigates some land on the south side of that stream, where there is a reservoir to aid in regulating the distribution of the water. The present capacity of the ditch is greater than, or at least equal to, its decree of 153.4 cubic feet per second. This ditch has practically absorbed the Big Thompson No. 1 ditch and covers all the latter's land. It has acquired by purchase 28 cubic feet per second, and by the transfer of five individual rights 45 cubic feet per second more, carrying, therefore, 73 cubic feet per second of the Big Thompson No. 1 water. It covers nearly 9,000 acres and actually irrigates 5,000 acres or more. Its stock is divided into 108 shares, serving 80 acres each, valued at $400 per share; the cost of maintenance is less than $900 per year, and an assessment of $14 per share yearly covers all costs of maintenance, superintendence, and a certain amount of interest on borrowed money. Each share is presumed to furnish 60 "inches" when needed, though much less suffices. This ditch has three decrees, as follows:

Decreed rights of Hillsboro Ditch.

Date.	Quantity.	Area.
	Cubic feet per sec.	*Acres.*
October 15, 1874	8.25	300
April 15, 1878	99.46	1,800
October 6, 1881	45.69	3,000

There seems here to be rather a flexible rule for estimating the amount of water required per acre in granting the decree. Its construction is said to have been "difficult," probably due to the fact that an attempt was here made to get water up on to the mesa. Others of later construction are accounted "easy of construction" under similar circumstances.

THE HANDY DITCH.

The head gate of this ditch (see frontispiece) is the highest on the river, and the ditch covers the highest irrigated land on the south side. It is about 22 miles long, covering some 15,000 acres and actually irrigating more than 12,500. Its capacity is about 250 cubic feet per second, and it is used largely to fill the numerous private reservoirs under it. A large part of the area irrigated lies on the Little Thompson slope, which is accounted the best land in the district; certain it is that the land under this and the Home Supply Ditch lies ideally for irrigating and is wonderfully productive, and, taken as a whole, will average $50 per acre in price. This ditch is unfortunate in the smallness of its first decree and in its not possessing reservoirs to furnish late water. Both these defects are largely counterbalanced by the numerous private reservoirs under it. This ditch is especially famous on account of its lawsuits, and will be frequently referred to hereafter in that connection. As to its priorities, it has one of February 28, 1878, for 31.2 cubic feet per second and one of December 15, 1880, of 141.23 cubic feet per second.

The findings of the referee are different in this case from those to which attention has been called. The application states that there were 10,000 acres under the canal February 28, 1878, and that the amount claimed was 520 cubic feet per second. The referee then says that the amount of water appropriated was 31.2 cubic feet per second. Of his own volition he states: "I find, further, that the ditch was enlarged." The owners never claimed an enlargement in their application. The facts were that the ditch was built the first year full size to a rock cut, and beyond the rock cut full size again; but in order to get water for the crops of that year the cut was not built full size, but was completed two years later. The referee evidently considered the capacity of a ditch the capacity of its smallest part, and the court agreed with him. This was really the beginning and cause of the Handy Ditch's subsequent legal contests, though most of the cases involved in no way the decree to the Handy. The Handy Ditch Company has acquired by purchase the Big Thompson Irrigation Ditch, known as No. 5, with a priority of 78 cubic feet per second. As stated before, it is now allowed to draw 20 cubic feet per second of this water, and it has had transferred to it 6 cubic feet per second from No. 2, or the Big Thompson and Manufacturing Company's Ditch, so that it has 26 cubic

DAM AND HEADWORKS, HOME SUPPLY DITCH, BIG THOMPSON RIVER.

feet of water per second of very early priority, besides its first 31.2 cubic feet per second to supply domestic needs and late crops.

THE SOUTH SIDE DITCH.

This is a small ditch heading just inside the canyon, with only the Handy and Home Supply ditches above it on the river. It covers about 2,000 acres and irrigates nearly that area; it has a capacity of less than 35 cubic feet per second, though its decree calls for 50.3 cubic feet per second. The acreage and capacity at the time of the decree was about one-half of this amount, the enlargement being made in consequence of the purchase of water from the Big Thompson and Manufacturing Company's Ditch. The amount purchased was 6 cubic feet per second and the price $1,500. The ditch stock is divided into 175 shares at $50 per share, and a share is supposed to irrigate 10 acres. The land under this ditch has an average value of $40 per acre. The cost of maintenance and of superintendence is about $100 per year each.

THE HOME SUPPLY DITCH.

This ditch, the second on the river, is likewise one of the largest and most important in the district. It, with the Handy, irrigates by far the greater part of the land on the south side. It is finely constructed, with a good masonry dam in the river (Pl. II). The upper end is in a rock cut, and its rating flume is the most permanent on the river. The canal with its laterals is some 32 miles long and covers 19,000 acres, actually irrigating 18,000 acres. It has the best reservoir system in the district, running water from its reservoirs directly onto the land and exchanging with the river. Notwithstanding its very late priority, its lands are as well supplied as any. Under it are a relatively large percentage of the late crops; winter wheat, in particular, being raised, the acreage of which is increasing every year. The yield is in excess of 30 bushels of wheat per acre. There are 2,001 shares in the company, each 15 shares equal to a 160-acre water right. The value per share is $150, practically $10 per acre. In 1881 this company acquired the Lone Tree Reservoir and in 1888 the Mariano Lake. It has purchased 24 cubic feet of water per second from the Big Thompson Manufacturing Ditch, at a price said to be $1,000 per cubic foot per second. Figuring the value of a foot from the value of the shares, it would be $2,250. As this, however, includes reservoir rights as well, it is hardly a fair estimate of the value of a cubic foot of water per second. It is said by parties under the ditch that as much water is run in September as in June. This is nearer the truth under the Home Supply than under any other ditch or system of the district; at the same time its entire accuracy is open to question.

The ditch has acquired by the transfer of the shares of five different

parties 10, 4, 3, 3, and 2 cubic feet of water per second from the Big Thompson No. 1 ditch, for the carrying of which they charge 50 per cent of the water carried.

The cost of operation is for superintendence $1,500 and for repairs about $350 per year.

RESERVOIRS.

The reservoir system of district No. 4, while not as complicated as that of district No. 3,[a] is as well developed and as efficient. No more water escapes from district No. 4 than from district No. 3, and probably not as much. Its inlet ditches are comparatively short and the reservoirs lie at a good elevation, making it unnecessary in all but one case to discharge into the river and take water in exchange.

Almost all the reservoir sites are found to be natural depressions. These depressions often form natural reservoirs and contain water drained into them from the surrounding lands; others have the rim depressed at one point, and through this break the water escapes. In improving the sites a dam is thrown across the lowest point in the rim and the capacity of the reservoir largely increased. The dams are generally of earth riprapped with stone, with outlet pipes running through them, controlled by valves.

The soil in these reservoirs being the washings from the surrounding lands and of an adobe or clay character, is almost impervious, and forms an excellent bottom, through which very little water escapes.

Very few reservoirs have been made by placing dams across water courses, as they are much more expensive, as well as more dangerous, the sudden floods often endangering the structures and necessitating the construction of proper wasteways and constant watching. In such reservoirs, also, considerable annoyance and expense is incurred on account of the necessity for allowing the natural flow to pass unimpeded through them when the water is needed for direct irrigation by the ditches below.

Fortunately, there is an abundance of good natural sites in this district other than those found in the beds of the streams. Some excellent sites which exist in the mountains have not been utilized, as those in the immediate vicinity of the farms could be constructed more cheaply and more easily controlled. Storing water in the mountains necessitates the use of the river channel to convey it to the head of the ditch which carries it to the land irrigated. Here a division of the reservoir water and the natural flow of the stream must be made.

[a] In U. S. Dept. Agr., Office of Experiment Stations, Bulletin No. 92, on "The Reservoir System of the Cache la Poudre Valley," by the late E. S. Nettleton, will be found an excellent description of the reservoirs and reservoir sites of district No. 3. What is there said is equally true of the reservoirs of district No. 4. The general physical characteristics and the method of management, construction, and distribution are the same.

Losses occur in transit from numerous causes. To have a keeper at the lake is an expense, and communication between the lake and the farm is slow and difficult.

On the Big Thompson few reservoirs are owned by the ditch companies or by the users in common; the majority being private in their character, are used principally to irrigate the lands of the owners. If a reservoir owner has a surplus, however, he may sell water to his neighbors. Becoming a chattel when stored, reservoir water is under the absolute control of its owner, and valuable accordingly.

Reservoirs were developed much later than ditches, for until a scarcity was felt there was no necessity for them. Prior to the time, however, when such necessity existed, reservoirs were, nevertheless, coming into existence through natural causes and through no effort on the part of the irrigator. In the natural depressions mentioned, the surplus, the waste, and seepage water found a resting place. Land being abundant, no effort was made to drain the natural lakes so formed, which were found to be useful for stock purposes. Later fish were put into them, ice was cut, and in numerous ways their convenience and value became apparent. When the ditches were not running, it was soon discovered that by a little labor in excavating a trench through the rim water could be taken from these lakes for irrigating early crops or for plowing, and the uses naturally grew as water became more scarce. This was the condition until about 1880, when it began to be recognized that the rivers were overappropriated during low water, and the ditches constructed about that time saw in stored water their only assurance of an adequate supply. The Home Supply Ditch Company was the first deliberately to build a canal in the face of a short supply with the avowed purpose of storing the floods and using reservoir water as its main supply. Its wisdom has been demonstrated by the success of this canal and reservoir system, which, notwithstanding the lateness of the decree, always has an abundance of water. Before 1880 there was little diversity in the crops sown in the district. Aside from native hay, grain was the principal product and required irrigation at about the time of the maximum discharge of the river. These conditions, together with a more evenly distributed as well as later maximum flow than now, delayed the recognition of the overappropriation of the river and the necessity for reservoirs. The increase of the area cultivated at length showed the overappropriation and the growing of alfalfa increased the demand for late water for the irrigation of its second and third crops.

Requiring little engineering skill and but a small amount of capital and labor, the construction of the reservoirs kept pace with the demand until now the time has arrived when there is a scarcity of water for storage purposes. With the numerous demands upon the river, unless the reservoir has a fairly early priority, or is small, or has a very large

supply canal, it often happens that the short high flood period is not sufficient to fill the reservoir. This condition has retarded reservoir construction somewhat, the greater growth being in increasing the capacity of reservoirs already constructed and in enlarging the inlet canals. There are numerous undeveloped sites in the district, the more important of which are enumerated further on. By the use of these and the enlargement of the inlet canals very little water indeed would escape, and then only in time of unusual floods.

The great incentive at present for the construction of reservoirs is to supply water to late crops; sugar beets are becoming a factor in the water problem and require considerable late water; potatoes likewise require irrigation late in the season, and winter wheat, now so popu-

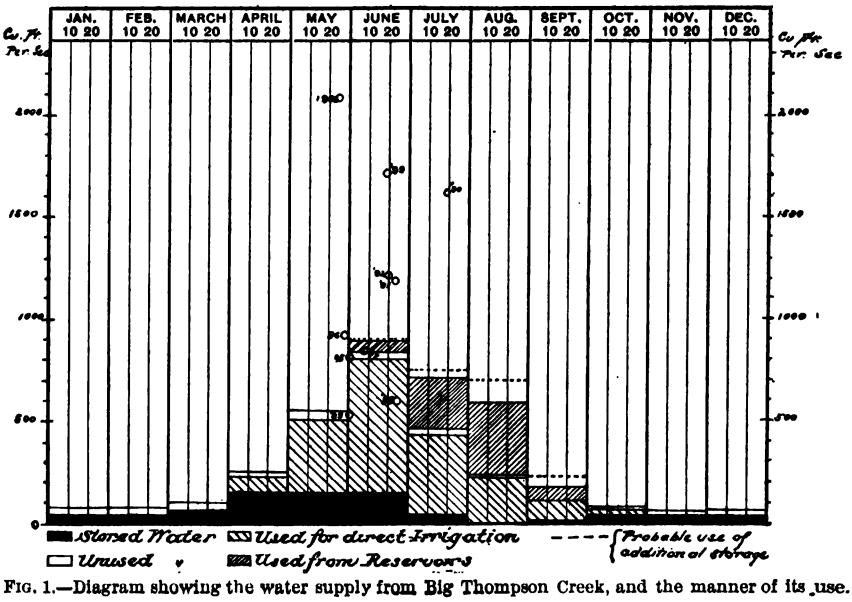


FIG. 1.—Diagram showing the water supply from Big Thompson Creek, and the manner of its use.

lar, must be irrigated in the fall. With alfalfa, followed by potatoes and beets, and these in turn followed by winter wheat, even the rotation of crops does not lessen the demand for reservoir water. In the diagram (fig. 1) the average water supply for the different months of the year is represented graphically, platted to accord with the figures given in the tables of discharge. It will be seen that there is a surplus available for storage from October to June, while there is a demand for stored water during June, July, August, and September. On the plat the dotted lines represent the average amount of water used during each month. In arriving at these quantities estimates were obtained from several of the former water commissioners and from the present commissioner of the amount of water used for direct irrigation each month and the amount drawn from reservoirs. They furnished esti-

mates also of the percentage which would be used each month, if the irrigators under the present crop conditions could have the water whenever they wished.

Similar statements and estimates were obtained from several of the officials of the larger ditches and from such consumers as could be reached. With these statements, and a knowledge of the average flow for each month, the conclusions were as shown on the diagram. The opinions and figures were remarkably uniform in general statement, the greatest difference of opinion being as to the relative use of water for July and for August. Those contending that the use was greater in August were under a ditch with good reservoirs, while those who believed it was the greater in July were irrigating with water direct from the river. The commissioners were inclined to believe the use in July was the greater, and, considering the flow in the stream, such appears to be the case. The figures on which the diagram is based are given in the following table:

Water supply from the Big Thompson River, with the average amount of water used, various uses to which it is put, and probable time of use of additional stored water.

Month.	Direct irrigation.			Average amount of reservoir water.		Water unused.	Possible increase of storage.	Time of increased use.
	Average discharge of river.	Average used.	Amount necessary to supply demand.	Used.	Stored.			
	Cubic feet per sec.	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*
January	60	00	00	00	30	30	20	.....
February	60	00	00	00	30	30	20	.....
March	100	00	00	00	70	30	20	.....
April	250	75	75	00	150	25	20	.....
May	544	350	350	00	150	44	30	.....
June	834	650	1,000	50	150	34	20	10
July	465	400	800	250	35	30	15	40
August	230	220	700	350	00	10	5	106
September	111	100	400	66	11	00	00	50
October	71	25	25	00	30	16	16	.....
November	54	00	00	00	30	24	20	.....
December	60	00	00	00	30	30	20	.....
Average	237	.....	.....	.....	.....	.....	.....	.....
Acre-feet	171,729	100,271	.....	43,170	43,170	18,287	12,389	12,389

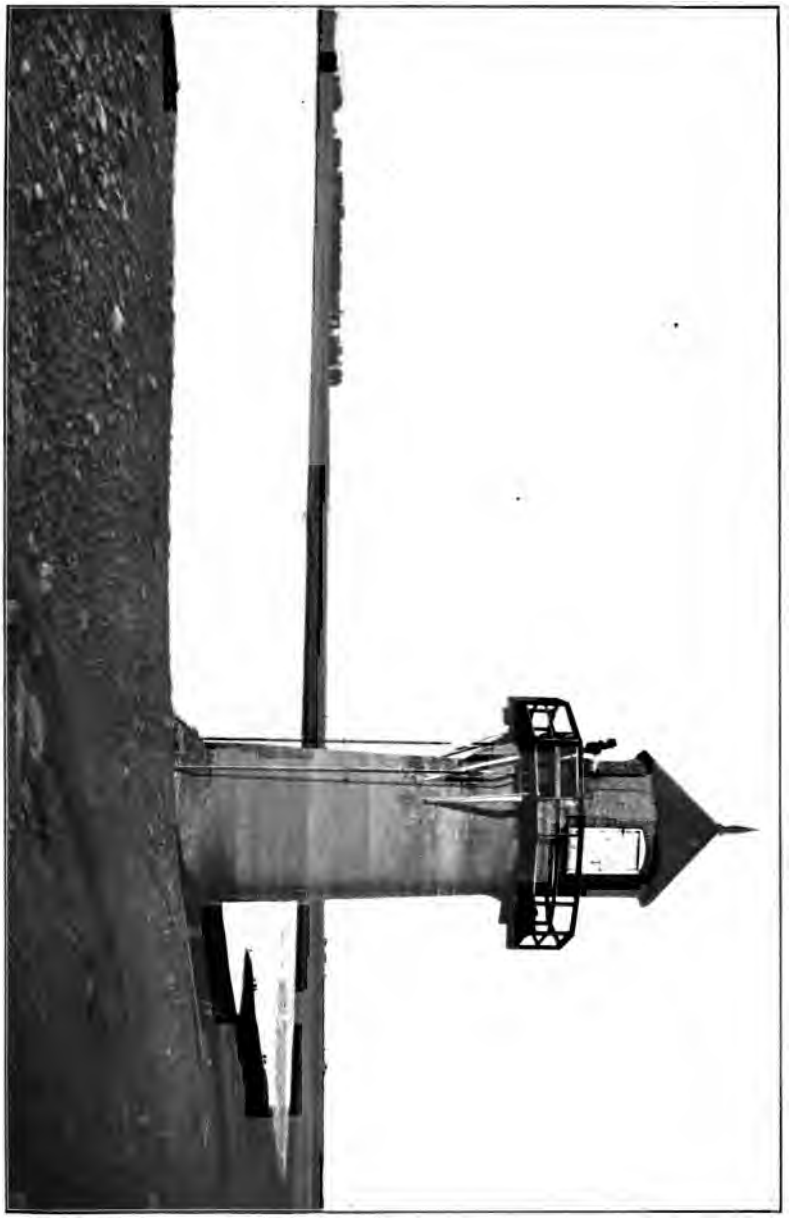
The first column is simply the recorded flow of the stream; the second is an average of the amount of water used directly on the land, and is the result of a comparison of the reports of the superintendent and of the commissioners of irrigation who have direct control of the water distribution. The flow of the stream as recorded, and the fact that much of the loss is during extensive floods, though this loss is generally for a very short period, have been considered in making the table. The conclusions given in the third column are taken from figures furnished by the superintendents and commissioners, and it is probably the most nearly correct column in the table. After June and until October there is a greater demand than the average flow of the stream, and yet during June and July water is stored. The demand

is not a fluctuating quantity, but is steadily increasing or decreasing, while the flow of the streams is fluctuating, often violently, during these months. Also, while the average demand, in June, for example, is for 1,000 cubic feet per second, the greater part of the demand is in the latter part of the month. The greater part of the storage is done therefore early in June. In July the storing is done during the periodical rises only, while during the winter months the loss of what might be stored (see sixth column of table) is occasioned largely by the freezing of the ditches, and for that reason in estimating the additional amount that might be stored, about one-third is deducted from the total loss at present. A little care would almost always permit the entire amount in the river to be stored. The last column is an exhibition of when the additional water so stored would be used, according to those best informed on the matter. It is agreed that at present the early water is forcing the planting of early maturing crops, though these are not as profitable as the later ones.

Development in reservoirs is not restricted to the water now going to waste, for it will be profitable to store the water which even now is being used for direct irrigation and save it for the more profitable late products. With potatoes producing an average of $100 annually per acre, and beets two-thirds that amount, neither using much more water in a season than is necessary for a $20 alfalfa or wheat crop, the building of what we might call retarding or temporary storage reservoirs can not be other than profitable. To the construction of retarding reservoirs the demand for direct irrigation acts as a check, and the true status of the right of such reservoirs to store water is yet to be determined. In some districts it is the custom to allow temporary storage of water taken from the river on a "direct irrigation" priority; in others it is looked upon as illegal. One side argues that water alike in quantity and time would be taken from the common source in any case, and that it makes no difference to later ditches whether it is actually applied at once or after a short interval. The other side contends that only when not needed for immediate use may it be stored, and that the storing will increase the area irrigated and the consequent withdrawal of a larger total amount during the season. There can be no question as to which would be for the greater good of the community as a whole, but the established rights of individuals must be respected.

Returning again to the diagram and table, we find that 237 cubic feet per second represents the average discharge for the year, or about 171,729 acre-feet; that 100,271 acre-feet are used for direct irrigation; about 43,000 acre-feet are stored; about 18,000 acre-feet escape, and it is possible to store a little over 12,000 acre-feet more than is stored at present.

It appears that during April, May, and June equal amounts of water are stored. The commissioners differ somewhat as to this, but incline to the belief that more is stored in June. A necessary correction,



OUTLET TOWER, LAKE LOVELAND.

however, which they have not considered is the amount of water which is stored in fact, but is supposed to be diverted for direct use. The private reservoirs especially practice storing their pro rata of ditch water when they do not need it for direct use. Many systematically store water at nights and on Sundays, and in the aggregate this is no inconsiderable amount. The practice is indulged in very early in the season, as the reservoirs are empty and a general fear exists that they may not be entirely filled; later, when many of the reservoirs are full, this practice stops. For this reason the quantity stored during April and May is made larger than would at first thought seem proper.

On the diagram will be noted small circles scattered over the portion representing the months of May, June, July, and August. These, with the year indicated, represent the highest water for these years.

In the following descriptions of reservoirs those under each ditch are given together to enable one to form an estimate of the value of the reservoir and ditch as a system. The list contains many reservoirs of little importance, and these are inserted more with a view to making the list complete than to their value.

RESERVOIRS UNDER THE LOVELAND AND GREELEY CANAL.

LAKE LOVELAND.

This is the largest lake in the district, and one of the most noted in the State, not only for its size and capacity, but for the amount of land dependent upon it for water. The land irrigated has generally a ditch right, as well as reservoir right, reserving the latter until late in the season.

The reservoir covers 472 acres, and is located near the north boundary of the town of Loveland. It is a natural depression which was enlarged and improved by the building of a dike along the south side, 8 feet high, 20 feet wide on top, with a slope of 3 to 1 on the inner face and 1½ to 1 on the outer face; the inner face is well riprapped with stone. A tunnel, lined with concrete, three-fourths of a mile long and 5 feet in diameter, furnishes ample outlet facilities and discharges into the Loveland and Greeley Canal. A brick tower near the south side of the lake at the upper end of the tunnel contains the mechanism for opening and closing the gates (Pl. III). The gates are of iron sliding in grooves outside the tower and operated by a threaded rod, worm gear, and wheel. The amount discharged through the tunnel seldom exceeds 350 cubic feet per second. The inlet ditch, known as the Old Barnes Ditch, has its head gate 3½ miles above the reservoir, and a capacity of more than 400 cubic feet per second, though on account of the danger of breaking where it runs along a side hill, 375 cubic feet per second is about the maximum carried.

The reservoir has a maximum available capacity of 13,000 acre-feet and an unavailable capacity of 7,000 acre-feet. At the various depths it has the following capacities:

Capacity of Lake Loveland.

Feet.	Acre-feet.
0	[a] 7,000
5	1,000
10	2,000
15	3,300
20	4,700
25	6,300
30	8,000
35	9,900
40	13,000

[a] Unavailable.

The cost of the construction of the reservoir was about $125,000, and the present cash value of each of the 300 shares is $750. One hundred and thirty-five shares were sold some years ago, 100 being taken on a guaranty before the work of construction was begun, and 35 sold at irregular intervals during the seven years since the reservoir has been in operation. During the present year some 40 shares were sold, more than during the entire time previously, and at the full cash value. A sudden awakening seems to have come as to the value of reservoirs for late water, due in a measure to the advent of the sugar beet. It is probable that the remainder of the 300 rights will be disposed of before many years, and at an advanced price.

In delivering water from the reservoir the wishes of a majority of the farmers have been considered in determining the time when the water is to be run. The difference in location and a considerable difference in the crops raised on the upper and lower parts of the ditch often caused a conflict between these two sections on this point. The lower ditch, having a considerable majority, generally had its way. It is proposed, however, hereafter, so far as is practicable, to consider the needs of each farm and to divide the ditch into at least two sections. A flow of 1.44 cubic feet per second is accounted the equivalent of an 80-acre water right, and that amount is turned out for each right, measured over a weir, the total amount being measured in a rating flume near the mouth of the tunnel. In the description of the Loveland and Greeley Canal it is stated that more than 21,000 acres were actually irrigated by it. It is interesting to know that after the 1st of July practically no water direct from the river is used on 17,000 acres of this land, the other 4,000 being served by the old free rights. Much of this 4,000 acres possesses reservoir rights also. There are in use 175 shares of reservoir rights of 80 acres each, or in all 14,000 acres.

During the year 1901 the following runs were had from the lake on this land:

Runs of water from Lake Loveland, 1901.

Date.	Days.	Cubic feet.	Acre-feet.
July 21 to July 27	6	91,806,000	2,108
August 2 to August 7	5	78,834,000	1,809
August 14 to August 19	5	69,200,000	1,589
August 26 to September 1	5	84,034,000	1,929
September 6 to September 13	7	79,021,000	1,814
Total	28	402,895,000	9,249

At the end of the season there remained 9.5 feet in the lake to be drawn off, about 2,000 acre-feet. Without counting loss, which is probably made up by seepage into the ditch, the reservoir furnished practically a depth of 8 inches over all the land possessing reservoir rights.

The amount of water run into the ditch, as nearly as can be determined, was, prior to April 30, 2,914 acre-feet; in May, 5,139 acre-feet; in June, 15,900 acre-feet; in July, 7,068 acre-feet; in August, 1,916 acre-feet; in September, 870 acre-feet—a total of 38,946 acre-feet; but this water was subject to the demand of nearly the entire 21,000 acres, making a depth of 1.85 feet.

THE BIG CUT RESERVOIR.

This reservoir is located in sec. 6, T. 5 N., R. 67 W., covers 76 acres, and contains 1,150 acre-feet of water when filled to its full capacity. It is filled from the Loveland and Greeley Canal during high water.

DARROUGH LAKE.

This is situated in secs. 4 and 9, T. 5 N., R. 68 W., has a capacity of 400 acre-feet, and is about 60 acres in area. It is supplied with water from the Loveland and Greeley Canal.

THE SANBORN RESERVOIRS NOS. 1 AND 2.

These reservoirs are owned by private individuals. Together they are supposed to contain 400 acre-feet, but have not been used to any considerable extent. They can be filled from the Loveland and Greeley Canal and gather some seepage water. They were intended to supply domestic water in the immediate vicinity of Greeley by means of a pipe line run from them.

The reservoir sites under the Loveland and Greeley Canal are few, viz, the Dawkins, in secs. 21 and 28, T. 5 N., R. 67 W.; the Basch, capacity 25 acre-feet, in sec. 10, T. 5 N., R. 68 W.; the Steele, with an area of 7 acres and a capacity of 25 acre-feet, and the Steele and

Phillips, in sec. 16, T. 5 N., R. 66 W., 10 acres in area and having a capacity of 35 acre-feet. These are unimportant in point of capacity and can be used only for very limited areas.

RESERVOIRS UNDER THE LOUDON DITCH.

Under the Loudon Ditch there are several small reservoirs and some very fine reservoir sites; the main difficulty met with, however, is the distance of the better sites from the head gates of the supply canals. The reservoir sites are natural depressions without outlets and consequently tunnels or cuts must be made through which to draw the water. On account of the loss of head and the location of the basins below the head gates of the ditches of the district an exchange of water from them with other ditches is difficult. If discharged into the river there would be no ditches below to take the water and use it, as the Mariano Lake now exchanges with the lower ditches to almost their full rights.

BENSON LAKE.

Benson Lake is situated in the N. ½ of sec. 10, T. 5 N., R. 69 W. It is owned by A. S. Benson, of Loveland, and used by him to supplement his supply from the Barnes Ditch for about 400 acres of land. By the use of the reservoir Mr. Benson says the amount of land irrigated is twice what it otherwise would be. The reservoir has an available capacity of about 300 acre-feet.

THE BENTAL.

This is a small lake of about 10 acres in sec. 2, T. 5 N., R. 69 W., filled from the Loudon Ditch and supplements the irrigation of some 60 acres. The capacity is about 50 acre-feet.

SEVEN LAKES, LOUDON AND BOYD LAKES.

These form a system lying close together some 3 miles northeast of Loveland, and for the most efficient use are largely dependent on each other. The Loudon Lake, which is the most northerly, has been in operation for some time, and by decree has a right to 50,000,000 cubic feet, or 1,148 acre-feet. Its priority is dated February 24, 1883, and is the sixth on the Big Thompson River. This lake is located mainly in sec. 30, T. 6 N., R. 68 W., on the line of the Loudon lateral, and is used as an auxiliary supply for some 2,000 acres of land on the Cache la Poudre slope. It covers about 65 acres to a depth of 28 feet. The area of land irrigated by the Loudon lateral by reason of the availability of the water from this reservoir is at least doubled. The reservoir, with its outlet ditch, was bought by the Seven Lakes Company. The year 1901 was the first season for the Seven Lakes and was fairly

satisfactory. What its future usefulness will be has not yet been determined, the first season developing a number of unforseen difficulties and conflicting legal claims.

The reservoirs are supplied partly by seepage and waste water, but this source, even augmented by flood waters, which are not inconsiderable, is entirely insufficient. Dependence must be placed, therefore, on a supply from the Loudon Ditch, and 40 shares in that ditch were purchased, the intention being to fill all the reservoirs through the Loudon Reservoir with water furnished to these shares. As water can not legally be stored when needed for direct irrigation an injunction immediately stopped the practice and the question will be finally settled in the courts.

In addition to this difficulty the Loudon Ditch Company does not feel bound to allow the use of the canal as a supply ditch for the Seven Lakes, at least not without compensation.

The Seven Lakes Company contracted with the Loveland and Greeley Ditch to carry 56 cubic feet of water per second to lands under that ditch. On account of the smallness of the outlet and the small difference in level between the lakes and the ditch, not more than 40 cubic feet per second could be discharged into the Loveland and Greeley Canal, and when the water in the reservoir had been lowered, 20 cubic feet per second was the most that could be drawn. Some difficulties in dividing the water of the reservoir and of the ditch developed, but these can probably be easily overcome as the conditions are better known.

With ample supply facilities, the capacity of the reservoirs could be increased by additional embankments 130,000,000 cubic feet, and by drawing off the low water in reservoirs Nos. 1, 2, and 3 into Boyd Lake 100,000,000 cubic feet of now unavailable water could be used. This, with the 330,000,000 cubic feet capacity at present, would make 560,000,000 cubic feet, or 12,856 acre-feet—almost equal to Lake Loveland. Most of this water would be used on the Cache la Poudre slope or at the lower end of this district.

Boyd Lake and South Lake, natural bodies of water separated by a low ridge, have been examined and reported on by Captain Chittenden, U. S. Army[a]. It is one of the best sites in the State. The plan outlined by Captain Chittenden is for the development of the greatest capacity of the lake. However, by filling the lake and sluicing out the cut to a less depth than was contemplated, the cost would be vastly less than the estimated cost under the Chittenden plan, and yet would be ample to store the available water.

Two small reservoirs exist in sec. 2, T. 5 N., R. 69 W., and cover some 10 acres each. Their combined capacity is perhaps 100 acre-feet, and they are used as an auxiliary supply on the lands of the owners.

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[a] House Doc. 141, 55th Cong., 2d session.

The reservoir sites under the Loudon Ditch are comparatively small and few in number, aside from the Seven Lakes and Boyd system.

There is a site belonging to A. S. Benson in the S. ½ of sec. 10, T. 5 N., R. 69 W., and one belonging to A. S. Benson and A. Rist in sec. 9, T. 5 N., R. 69 W. These have an area of 50 acres each and could possibly be made to have 15 feet of available depth.

George W. Alford has a site in the NE. ¼ of sec. 2, T. 5 N., R. 69 W., possibly 20 acres in area and 10 feet available depth.

The Fairport Lake, in sec. 13, T. 6 N., R. 69 W., is on the Cache la Poudre slope, connected with the Cache la Poudre by an inlet canal. It has an area of 53 acres and a capacity of 575 acre-feet. It contributes to the irrigation of some 1,500 acres.

RESERVOIRS UNDER THE HANDY DITCH.

Under the Handy Ditch there are, as previously stated, only private reservoirs, although the company will probably very soon take steps to obtain suitable reservoir facilities.

FRANK LOVELAND RESERVOIR.

This reservoir is located in the NE. ¼ of sec. 15, T. 4 N., R. 69 W., and covers nearly the entire quarter section. It has a capacity of 800 acre-feet, which, however, can be greatly increased. By the raising of the dike some 10 feet a capacity of 2,000 acre-feet could be obtained. As the reservoir has recently changed hands, it is probable that this will be done. At present it is not much used for irrigation.

THE DE FRANCE RESERVOIR.

This reservoir is located in secs. 4, 5, 8, and 9, T. 4 N., R. 68 W., and covers over 50 acres. It is used in irrigating some 600 acres of land and has a capacity of 250 acre-feet. It is most efficient in supplying late water.

THE KEE RESERVOIR.

The Kee Reservoir is located in the NE. ¼ sec. 17, T. 4 N., R. 69 W., and is filled through the Handy Ditch in the spring. It is a natural basin, with a dam some 12 feet high, and irrigates about 50 acres. Its capacity is not over 100 acre-feet.

THE BROWN RESERVOIR.

The Brown Reservoir is located in the SW. ¼ sec. 35, T. 5 N., R. 69 W., receives its supply from the Handy Ditch, and being just above the Home Supply Ditch, exchanges water with it. It has a capacity of 65 acre-feet and irrigates some 40 acres of land.

THE WILSON RESERVOIR.

This reservoir is located in the SW. ¼ sec. 20, T. 4 N., R. 69 W., is filled from the Handy Ditch, irrigates 100 acres, has an area of 30 acres, and a capacity of probably 150 acre-feet. It is proposed to enlarge this reservoir soon.

THE HUPP LAKE RESERVOIR.

This reservoir is in the NW. ¼ sec. 35, T. 5 S., R. 69 W., is filled from the Handy Ditch, furnishes late water for 160 acres, and has a capacity of 50 acre-feet, which could be doubled by building a high dam.

THE HUPP RESERVOIR.

This reservoir is located in sec. 28, T. 4 N., R. 69 W., has been practically abandoned, though it contains water from seepage. It was found to injure the land below it, while available to irrigate little land. The capacity was 50 acre-feet.

THE BERTHOUD TOWN LAKE.

This lake is used for irrigation in the town of Berthoud, is small and irrigates little land.

THE JANSEN RESERVOIR.

The Jansen Reservoir is located in sec. 13, T. 4 N., R. 69 W.; covers 40 acres; it is supplied now from waste and seepage water; is unused at present, but could be developed to cover 100 acres, with a capacity of 1,000 acre-feet.

THE HUMMEL LAKE.

This lake is in sec. 17, T. 4 N., R. 68 W., is owned by J. C. Hummel and is used to irrigate the owner's land, some 350 acres. It covers an area of 60 acres and has a capacity of 250 acre-feet. It is filled through the Handy Ditch in the spring.

BEASLEY LAKE.

Beasley Lake is in sec. 11, T. 4 N., R. 69 W., filled by the Handy ditch, is owned by the Loveland Lake and Ditch Company. It covers 155 acres and can be drawn off for a depth of 19 feet or about 1,800 acre-feet. It furnishes water to some 2,000 acres, largely potato and sugar-beet land. It cost $14,000 to construct, and is valued at $50,000.

THE WELCH RESERVOIRS.

These are five in number and probably the most important under the Handy Ditch, especially if developed and used to their full capacity. The two more northerly reservoirs, Nos. 3 and 4, are not used at present. The capacity of the five is 4,400 acre-feet. No. 1, the largest,

covers 127 acres, and has a claimed capacity of 2,500 acre-feet. Nos. 2 and 5 have a combined capacity of 415 acre-feet. The reservoirs at present serve about 800 acres.

THE CHAPMAN RESERVOIR.

The Chapman Reservoir covers about 70 acres in sec. 32, T. 5 N., R. 69 W., and irrigates probably not more than 80 acres. Another smaller reservoir in the same section is used for stock purposes principally.

Some other sites and reservoirs exist under the Handy Ditch, but little could be learned concerning them. The Smith and Welty Lake, in sec. 15, T. 4 N., R. 68 W., has an area of 25 acres and a capacity of 100 acre-feet. The Berthoud Lake, in sec. 11, T. 4 N., R. 69 W., has an area of 40 acres and a capacity of 250 acre-feet. The Welch Lake, in sec. 25, T. 5 N., R. 69 W., has an area of 30 acres and a capacity of 200 acre-feet. In secs. 17, 20, and 21, T. 4 N., R. 69 W., are some very fair reservoir sites. Mr. George Zwick owns a good site in secs. 17 and 20, T. 4 N., R. 70 W. W. T. Newell has a site in sec. 18, T. 4 N., R. 68 W., with an area of about 150 acres. It could be filled from the Handy Ditch and furnish probably 1,500 acre-feet of water.

In the filling of reservoirs under the Handy Ditch the stockholders are permitted to store water in proportion to the amount of their stock, if they prefer to do so. As between themselves, the water is always divided in proportion to the stock held by each, and no restrictions are placed on the use to which it is put. On account of the smallness of its first priority and the necessary abundance of water in the river before the ditch can draw on its second priority, it is not possible to store water "needed by other ditches for direct irrigation." Whenever the ditch is running 50 cubic feet per second or less it is probable that every user needs his full amount for direct irrigation.

RESERVOIRS UNDER THE HOME SUPPLY CANAL.

The reservoirs under the Home Supply Canal are both large and important, and the values of the water rights and of the land equal the oldest rights on the river.

It is estimated by those best acquainted with the practical working of the Home Supply system that at least three times the area is now irrigated that could be served without the Mariano and Lone Tree lakes; that is to say, 18,000 acres are now irrigated in place of the 6,000 possible with the ditch alone. The land is estimated to be worth two-fifths more with than without reservoir rights; its value under this system being from $40 to $60 per acre.

Under this system water is sometimes rented to others than stockholders, the price being $12.50, equal to $1.25 per acre per year, which, considering the certainty of supply and the ability to use it at any time, is very reasonable.

The division of water is somewhat unique. As long as there is a supply in the ditch and the reservoirs are not taking it for storage, the stockholders have what is called "free" water, and no account of its use or distribution is kept; but when the reservoirs begin to supply the demand a conservative estimate is made of the amount of water in the lakes available for use, and this amount is divided equally among the 2,001 shares, and each stockholder is credited with his amount in cubic feet. An accurate account is kept of the amount each stockholder draws, and this is charged to him. He is permitted to draw the full amount as soon as he pleases. When the estimated amount has been drawn off, if there is water in the lake another credit is made as before, and the additional amount can then be demanded. By this system economy is encouraged, a high duty is obtained, and the easy rotation of crops and the planting of whatever seems best are made possible. It eliminates also many causes of controversy.

In acquiring its reservoirs the Consolidated Home Supply Company purchased in 1881, with $5,000 worth of its stock, the Lone Tree site. The company expended $12,000 on its dam and $10,000 on its tunnel and outlets. (Pl. IV.) It has a priority dated August 31, 1881, for 400,000,000 cubic feet. To acquire the Mariano Lake the company paid $6,000 for the land and right of way through the Rist Ditch, agreeing to enlarge and maintain it for its use. It expended $4,000 on the dam and outlet. (Pl. V.) The lake has a priority dated October 1, 1875, amounting to 180,865,000 cubic feet. With riprapping and other expenses, the cost of both reservoirs was certainly not over $50,000; this expenditure has increased values of shares probably $100 each, a total of $200,100, and has increased the value of the 18,000 acres irrigated probably $20 per acre, or $360,000—all of which goes to show the value of reservoir water.

In 1901 the distribution of water from the reservoirs began on June 1; a number of days of "free" water intervened, but from that time to the end of the season water was run continuously from one or both of the reservoirs. It was stated by the secretary that as much reservoir water was used in September as in June, and that the tendency for a number of years has been to use the water later each year. He also stated that the expenses of repair, maintenance, and distribution would not exceed $2,000 per year, or about 11 cents per acre irrigated, and with the value of rights at $150, allowing 6 per cent interest, the total cost per year per acre would amount to about $1.

The Mariano Lake discharges its water into the river, the discharge being limited by the amount to which the ditches below are at the time entitled by their priorities. The ditch takes from the river above a like amount, thus enabling its owners to use the water in the regular way, and the effect is the same as though the reservoir were at the head of and above the ditch. The capacity of Mariano Lake is

probably now equal to its decreed priority, but it could be enlarged to hold at least one-third more than that amount. The Lone Tree Lake has a capacity of nearly twice that of the Mariano Lake. Being high enough to irrigate most of the lands under the ditch, it does not exchange water with the river. Such lands as lie above it are supplied by that taken in exchange for the Mariano Lake water.

The following lesser reservoirs are also under or supplied by the Home Supply Ditch:

The Rist Reservoir, supplied like Mariano Lake, from the Rist Ditch, covers some 40 acres, and is used to irrigate the lands of the Buckingham estate, to which it belongs. It has a capacity of 115 acre-feet.

The Big Hollow Reservoir, a seepage reservoir in sec. 27, T. 5 N., R. 68 W., has a capacity of 30 acre-feet.

The Allen Reservoir, 6 acres in area, in sec. 6, T. 4 N., R. 67 W., is also a seepage reservoir, with a capacity of about 85 acre-feet, which may be increased.

The White-Butler Reservoir, on the south side of the Little Thompson, has purchased rights from the Home Supply Ditch, but it is not properly in the Big Thompson district.

There is also one other reservoir on the south side of the Little Thompson, but it is supplied by the Hillsboro Ditch; name unknown. It has an area of 160 acres and has a capacity of 1,500 acre-feet.

DUTY OF WATER.

The data at hand scarcely justifies discussing at any great length the duty of water. To reach results of value would require an examination and classification of the soil under each ditch, the kind of crops raised, and measurement of the water used by each over a series of years. The following table gives, however, such data as has been collected:

Duty of water on Big Thompson River, 1901.

Name of ditch.	Under ditch.	Irrigated.	Water diverted.					
			January 1 to April 30.	May.	June.	July.	August.	September.
	Acres.	*Acres.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
Big Thompson and Manufacturing Co	2,000	1,300	.....	360	708	1,086	836	242
Farmers'	4,500	3,000	.....	360	2,410	1,338	504	40
Loveland and Greeley	30,000	21,000	2,914	10,278	15,900	7,068	1,916	870
Big Thompson and Platte River	1,800	1,500	300	1,544	3,080	1,836	1,043	908
George Rist	2,000	1,800	2,000	3,000	3,418	1,180	212	90
Loudon	13,000	10,000	1,938	2,962	5,706	4,504	1,770	390
Hillsboro	9,000	5,000	.....	4,466	4,884	3,950	1,938	1,220
Handy	15,000	12,500	3,000	6,000	7,832	2,612	1,660	640
South Side	2,000	2,000	.....	666	842	924	626	180
Home Supply	19,000	18,000	3,000	6,430	5,058	3,472	3,052	1,070
Big Thompson	3,000	640	.....	300	300	300	300	300
Big Thompson Irrigating	1,000	800	.....	.....	.....	.....	.....	.....
Rist and Goss	500	300	.....	300	300	400	.....	.....
Hill and Brush	1,000	900	.....	500	600	700	.....	.....
Total	103,800	78,740	13,152	37,166	51,038	29,370	13,857	5,960

FIG. 1.—OUTLET OF LONE TREE RESERVOIR.

FIG. 2.—WEIR JUST BELOW OUTLET OF LONE TREE RESERVOIR.

FIG. 1.—MARIANO RESERVOIR.

FIG. 2.—DAM OF MARIANO RESERVOIR.

Duty of water on Big Thompson River, 1901—Continued.

Name of ditch.	Total amount used.	Amount used.		Depth on land.	Duty of 1 cubic foot per second for 180 days.	Average diverted, 180 days.	Capacity of reservoirs under ditch.
		Direct.	From reservoir.				
	Acre-ft.	*Acre-ft.*	*Acre-ft.*	*Feet.*	*Acres.*	*Cubic ft. per sec.*	*Acre-ft.*
Big Thompson and Manufacturing Co	3,232	3,232	.....	2.50	143	9	.....
Farmers'	4,652	4,652	.....	1.55	230	12.9	.....
Loveland and Greeley	38,946	25,946	13,000	1.85	193	108.3	15,200
Big Thompson and Platte River	8,711	8,711	.....	5.80	62	24.2	.....
George Rist	3,600	3,600	.....	5.50	65	10	.....
Loudon	17,270	9,270	8,000	1.73	206	48	9,000
Hillsboro	16,458	14,958	1,500	3.30	108	45.7	1,500
Handy	21,744	16,744	5,000	1.74	205	60.4	7,200
South Side	3,238	3,238	.....	1.62	220	9	.....
Home Supply	28,382	14,382	14,000	1.58	228	78.8	15,400
Big Thompson	1,500	1,500	.....	2.34	153	4.2	.....
Big Thompson Irrigating	.....	.....	.....	.....	.....	.....	.....
Rist and Goss	1,000	1,000	.....	3.33	107	2.8	.....
Hill and Brush	1,800	1,800	.....	2.00	179	5	.....
Total	150,533	109,033	41,500	1.91	187	418.2	48,300

It may appear that in considering the duty of water the irrigating season of one hundred and eighty days is too long; that little irrigating is done in April or September. However, it is none too long, for much of the water is stored in April and represents what a cubic foot per second accomplishes with reservoir facilities or with a diversity of crops.

A comparison of the above table with the table giving the flow of the river (p. 13) reveals a remarkable agreement between the averages as estimated and what actually occurred in 1901, showing it to be an average year, a conclusion which is confirmed by reports just received from the superintendents and commissioners.

Allowing for the average amount of water escaping from the district, we have 150,533 acre-feet used and 18,287 acre-feet waste, giving 168,820 acre-feet as the discharge of the river, as compared with 171,729 acre-feet, the average for six years, as given in the discharge table; also 109,033 acre-feet used for direct irrigation, as compared with the average of 100,271 acre-feet; 41,500 acre-feet stored, as compared with the average of 43,170 acre-feet. In the table the Rist Ditch is given as diverting a total of 9,900 acre-feet, while using but 3,600; the difference, 6,300 acre-feet, was stored in Mariano Lake, and is accordingly charged to the Home Supply Canal, making its total 28,382 acre-feet instead of 22,082 acre-feet, the quantity diverted. The duty of water, it will be noticed, for the district is 187 acres per cubic foot per second, running one hundred and eighty days, and the land was covered to an average depth of 1.9 feet. If we add the amount of precipitation on the land, the total depth would probably be nearly 3.5 feet. Rain, however, does little good, since the greater part comes as light showers. Therefore, it is more to the point to consider simply the amount of water spread on the land.

It will be noticed from the table that the smaller ditches have a much lower duty than the larger ones, and those with reservoirs generally show a higher duty than those without. One cause of the low duty under the small ditches is that they cover the lowlands lying near the river, which, on account of their porous subsoil, require more water, and which, being generally rough, require a larger volume to force the water over the uneven surface. Another cause is that the smaller ditches in this district have the older and probably excessive decrees, making economy of use unnecessary. With these decrees and the poor construction and management of the ditches, it is surprising that the duty is not lower than shown.

It is hard to compare the duty under the ditches with and without reservoirs, as conditions opposite to the above exist under the ditches themselves. Being able to use water when and how it is most beneficial, the owners feel that economy of use means greater acreage irrigated. Loss, of course, occurs from the reservoirs through seepage and evaporation and partially offsets the economy practiced; but as this loss is not allowed for in the tables, it would appear that the better land irrigated, the better management, better ditches, and more economical use not only make up for all loss from the reservoir, but leave a large margin besides.

SEEPAGE.

Seepage and return water c upies a position secondary only to the supply furnished by the ditches and reservoirs. While in volume it is small, the regularity and reliability make such waters valuable in irrigation out of all proportion to the quantity. Seepage is in part a necessary result of irrigation, which can not under any condition be remedied; in part a result of the methods, which are theoretically wrong, but more economical in practical application, and in part the result of carelessness and ignorance.

The application of water to the surface of the ground must result in a certain amount percolating through the soil before it is either evaporated or taken up by the growing plant, and ultimately finding its way to the lower level of the water courses. No piping, cementing of canals, or economy of use can avoid this. The value of water and the cost of labor determine at what point it is economy to waste the one and reduce the other, or to save the one and increase the other. In practical irrigating, therefore, it is often economy to use more water than necessary in order to reduce the expense of labor in spreading it on the land, and this excess produces increased seepage. The possession of an old and abundant water right does not convey the right to use the privilege wastefully and to the harm of others less fortunate. In practice, however, it is impossible to prevent this abuse, which is

illegal[a] and to be condemned. It is a delicate matter to determine when and how much water is necessary to a piece of land; to step in and say only so much water is needed, when the court has determined that much more is needed. Only in the most flagrant cases is it possible for the water officials to interfere with what is conceived to be "established rights." Fortunately, much of this water is returned as "seepage," or, more properly, "waste" water. So prevalent is this waste that it has become a recognized and reliable source of supply and is almost synonymous with seepage. Nearly all filings, which claim seepage water, claim as well storm and waste water.

In the table below are given the claims for water filed during the last thirteen years on the Big Thompson, showing the activity in the different lines during the different years.

Filings for water on Big Thompson River, 1888–1900, as shown by the records of the office of the State engineer.

Year.	Reservoirs.		Seepage reservoirs.		Ditches.		Seepage ditches.	
	No.	Capacity.	No.	Capacity.	No.	Capacity.	No.	Capacity.
		Cubic feet.		*Cubic feet.*		*Cubic feet per sec.*		*Cubic feet per sec.*
1888	1	200,000,000			1	233.00		
1889					3	37.44		
1890	7	323,400,000			3	27.48		
1891	9	696,034,831			2	71.20		
1892			1	1,468,000			1	8.00
1893	5	3,329,666,000	4	7,282,000			1	3.50
1894	1	600,259,000	1	1,350,000			4	16.70
1895	1	1,305,972,360					2	17.50
1896			5	279,949,000			3	135.00
1897	1	42,469,000			2	26.50	1	6.00
1898	3	23,270,000	2	70,125,000	1	12.85	5	22.65
1899			4	248,000,000			8	53.50
1900	3	332,356,000					1	5.00
Total	31	6,853,427,191	17	608,174,000	12	408.47	26	267.85
Average		221,078,296		35,774,941		34.04		10.30

It might be said that most of the filings to 1893 were for reservoirs already in existence, as the Mariano, Lone Tree, and Loveland lakes. It will be noticed that the claims for both ditches and reservoirs claiming seepage water began in 1892, and that they have, generally speaking, increased in both number and capacity since that time. It will be noticed, also, that the seepage ditches and reservoirs are small as compared with the average appropriations from the river. The seepage ditches average but 10.3 cubic feet per second. Even this is too high, as one ditch alone in 1896 claimed 135 cubic feet per second, an obvious error. Excluding this we have the average claimed capacity of the seepage ditches 5.11 cubic feet per second, as compared with a claimed capacity of 34.04 cubic feet per second for ditches direct from the river. A like difference exists in the capacities of the two classes

[a]The statutes of Colorado expressly prohibit the excessive or wasteful use of water. Session Laws of Colorado, 1895, p. 197.

of reservoirs. The seepage of the district is probably not equal to the 25 claims for 132.83 cubic feet per second.

Seepage measurements on the river show that the return waters are probably close to 50 cubic feet per second, but much water does not reach the river, being taken up and diverted from the small draws and depressions where it first appears. As will be seen on the map, the seepage ditches, represented by the broken lines, do not head near the river, but under and near some of the large canals. This water does not appear in the measurement of the river, and its quantity can not be determined. It probably equals the amount which does reach the river, and the two should then equal 100 cubic feet per second. With an average flow, as shown heretofore, of 237 cubic feet per second, the seepage water would equal 42 per cent of the flow, and that returning to the river would be 21 per cent. On the Cache la Poudre River the return water, according to the investigations of Professor Carpenter, of the agricultural experiment station, is 30 per cent. Sufficient measurements of seepage have not been made on the Big Thompson to give more than approximate figures, but from data at hand 21 per cent seems at least a conservative estimate. In practice it is found that the Hill and Brush, the Hillsboro, and the Evans Town ditches are supplied largely during the latter part of the season with seepage water. The great value of seepage water is that its greatest flow occurs at the time of least flow in the river and supplies water when most needed.

In the consolidation of ditches it will always be necessary to maintain some on the lower river to take advantage of the return water. One large high line ditch on each side of the river with one or more seepage ditches below should be all that is necessary. The only objection to the use of seepage water appears to be that it is often quite strongly impregnated with alkali, and on evaporating leaves alkali deposited on the land. On the Big Thompson there appears to be very little trouble from this, because of the small amount of alkali in the district and because much of it has already leached and passed away. It has been observed that lands ruined by alkali have in time recovered and the alkali has almost entirely disappeared, the water, surface and underflow, passing through the soil having carried away most of the surplus. Much of mineral matter that is required by plant growth is contained in alkali, and when not in too great quantities it is a benefit to the soil, so that the leaching done by the surplus water used in irrigating deprives the land in one place of beneficial ingredients, which, concentrated and deposited on other land, makes them worthless. There are few spots which in their natural state contain alkali in such quantities as to make it harmful. It is the disturbance of its natural and even distribution through the earth by water and consequent concentration in spots or on the surface that makes it harmful.

Little has as yet been done in district No. 4 toward the reclamation of such lands as has been spoiled by seepage water, though there are several places of considerable area, probably 2,000 acres in all, which could be reclaimed with profit. The practice of draining land is of very recent origin in this State and the methods not well developed. The most common method and that giving best results is to dig an open trench along the upper edge of the swamped land or near the foot of the first raise of sufficient depth to intercept the inflowing seepage water; having done this, the water is conducted by open cut or pipe with sufficient fall to give a good velocity to the river or into some ditch where it may be exchanged or used for irrigation in the same manner as reservoir water. The amount of water thus reclaimed is often sufficient to pay for the expense of draining. Attempts to drain land with tiling under the surface and in the wet ground have not been successful. The abundance of land and the cost of tiling would in most cases make this method unprofitable, even if it were practical. After reclamation this land soon returns to its former condition, producing excellent second bottom hay, or, if put into grain, sufficient moisture is present to mature the crops without irrigation.

ADMINISTRATION AND DISTRIBUTION.

In the administration of ditches and reservoirs and in the distribution to the consumers there may be said to be two distinct sets of officials, those of ditch or reservoir companies of a private character and those of the State and district of a public character. A ditch or reservoir company has a president, secretary, and treasurer, with duties similar to those of any incorporated company. There is a man who patrols the canal and distributes the water to the consumers according to their proportion of stock or rights in the ditch. He is called the ditch "boss," "rider," or "superintendent," and acts generally under the direction of the other officers or directors. In most cases it is he who receives orders from the public officers and acts in conjunction with them.

Various devices and units of measurement are used in distributing the water; the more common, and those used in this district, are the division box for pro rata division and the ordinary culvert placed through the bank of the ditch. Where ditches are small the division box is quite satisfactory. This is a simple flume with level bottom and vertical sides, and of about the same cross section as the ditch. It is divided by a partition running lengthwise of it, the respective widths of the parts being in proportion to the number of shares to be turned out and to the number of shares in the ditch at that point. For instance, if there are 100 shares in all and 20 had been taken out above, leaving 80 shares in the ditch, and it was desired to turn out 10 shares

at this point, the box being 8 feet wide, one division would be made 7 feet wide, the other 1 foot wide, the part flowing into the smaller section being withdrawn from the side while the rest flows on down the ditch. Where the ditch is large, if the rider knows the amount of water at his disposal, he can turn out at any point a proportionate amount through the culvert, which is nothing more than a rectangular wooden pipe set through the bank of the ditch. By opening or closing the sliding valve at the end of the box he can regulate the flow. A rise or fall in the ditch will alter the quantity, of course, but the variation is probably not enough to affect the result seriously, and in any case a rise or fall will affect all alike. Where the water is sold by measure more accurate methods are desired. In such cases an additional measuring flume or weir is placed in the lateral, and the outlet gates are regulated until the proper depth is attained in the flume or over the weir.

The water in the river is divided among the different ditches in accordance with their priorities by the public officials, who are the water commissioners of the district, appointed by the governor upon recommendation of the boards of county commissioners of the counties in which they are to serve, the superintendents of irrigation for each division, and the State engineer, also appointed by the governor.

A water commissioner generally has charge of a single tributary or of a section of the main stream, and it is his duty to visit each ditch whenever it is necessary to regulate the amount of water flowing into it; he reports to the superintendent as often as necessary, stating the volume being carried by each ditch, the volume coming into and going out of his district, and the volume required to fill all ditches. The superintendent from these reports knows whether the water is being properly divided among the different districts, and if it is not orders the commissioner of one district to take more water, or less, and specifies the volume which should be allowed to pass into the district below, his orders being generally to close all ditches with priorities subsequent to a certain date. Protests against the actions of the commissioner are made to the superintendent, who passes upon the points in dispute. If his determination is unsatisfactory to any one interested, appeal may be taken to the State engineer and from him to the district court. The commissioners are subject to the orders of the superintendent, and both to those of the State engineer.

The commissioners are paid $5 per day for each day they are on duty, and the superintendent a like sum, his term of service continuing as long as any commissioner in his division is at work. In most cases this is for the entire year. In the winter the storing of water and the repair of head gates and placing of rating flumes and weirs are in progress, and the commissioner, besides attending to the dividing of the water for storage, usually gives directions and advice concerning

the requirements and the best methods of placing the gates and flumes. Superintendents and commissioners are paid equally by the several counties in which they serve (in some cases as many as ten or fifteen counties) and suffer the inconvenience of having their bills audited that number of times. The State engineer receives a yearly salary, paid by the State.

Besides the duty of distributing and dividing the water, the commissioner is required to gather crop statistics and to see that no water is wasted; and while he has no power to settle disputes over the distribution of water which is in the ditches, by mutual agreement he is generally made arbitrator in these family disputes.

The State engineer occupies a somewhat anomalous position in the irrigation system. While it is true the law places him at the head of affairs, he does not in fact act in that capacity unless some ditch or canal owner, feeling aggrieved at the rulings of a superintendent, appeals to him. In addition, the State engineer is required by law to gather and compile data of rain and snow fall, measure the streams, rate ditches, measure and keep records of reservoirs, examine their dams, supervise their construction or repair, condemn unsafe structures, and give professional advice to other departments of the State administration.

In this district, most of the ditches being owned by the water users, few written contracts exist, the conduct of the ditch officers being determined by the by-laws and constitutions adopted by the ditch companies. In most cases, whether the flow in the ditch be great or small, the water is distributed pro rata. Often, by agreement, when water is short one section of the ditch will use all the water for a few days, after which it is given to the consumers on the next section.

The cost of distribution is quite small and is approximately as follows for this district, which is fairly representative of the more important and better settled districts:

Cost of distribution of water, water district No. 4.

Officials.	Cost per year.	Paid by—
State engineer's office	$100	State.
Superintendent of irrigation	100	Counties.
Water commissioner	1,000	Do.
Officers of the ditch companies (12 companies)	2,000	Ditch companies.
Ditch riders (12 ditches)	5,000	Do.
Miscellaneous and extra help	1,800	
Total	10,000	

That is to say, the total cost of distributing the water from the river to the ditches is about $1,200, and from the main canals to the laterals $8,800, a total of $10,000 per year for perhaps 80,000 acres, or 12½ cents per acre.

In the management of small ditches the officers act without compensation, and the ditch riders receive perhaps $50 per year, the only time when they are on duty being when the ditches are being put in repair. It is seldom that the other officers receive compensation. It is only when the consumers are not the owners of the ditch and where the carrying of water is expected to return interest on the investment—where, as it is generally stated, water is "sold" by a ditch corporation to the consumer—that the cost of administration and distribution is any considerable item. In that case the manager, secretary, bookkeeper, treasurer, and a regularly employed attorney, as in any corporation, seem to be necessary, and are of course expensive. The cooperative ditch needs no such complicated machinery, and the success of cooperative ditches where corporation ditches have failed is largely due to this fact.

TITLES TO WATER.

Nearly all questions that come before either the administrative department or before the courts resolve themselves into the rights of the parties and their titles to the water. The title itself depends upon—

(1) The construction of canal and use of water, and the regularity of procedure in perfecting rights.

(2) The relation to other appropriators and their rights, including the right of transfer and sale.

(3) The nature of the grant, when issued, and of the privileges granted.

(4) The good faith shown by the grantee.

(5) His compliance with the provisions of the grant and nonabandonment of rights.

These five will include nearly every case in the conflict.

The right to the use of water for beneficial purposes was recognized by Territorial laws as early as 1861, and affirmed by Congress in 1866. The constitution of the State, adopted in 1876, declared water to be public property and subject to appropriation. These declarations were deemed necessary, as riparian rights had been upheld in the older States, and might by inference have become attached to Colorado.

At first water was taken from the river and used without thought of its ever becoming scarce or of there being a conflict for its possession. The lands then considered farming lands were so limited that there was apparently more water than would ever be used. Even at the time the decrees were granted many still entertained this opinion and did not enter their claims nor examine into the claims of others. In effect this does not deprive them of the right to water, but in the distribution the water commissioner ignores their claims, thus forcing applications for decrees. Prior to 1879 there was no requirement in

law relative to the filing of claims to water and adjudications of rights, though the necessity of some definite determination of the rights of different claimants had been recognized for some time prior to that year. As soon as a scarcity began to be felt the difficulty of dividing the water and the necessity of a clear statement of each consumer's right forced some action by the legislature, which up to that time had seemed unable to appreciate the importance of early action or unwilling to take the initial steps. There was a belief also that the ditch itself was evidence of a right; that water having once been used on land thereby becomes appurtenant to it. It was thought that a deed to the land conveyed the right to the water which had been used thereon. A series of years with abundant flow encouraged the irrigation of a good deal of land, but when these were followed at length by a year of small flow the necessity of depriving some one of water forced the establishment of a rule whereby this could be done. In the early days water was abundant for the land irrigated, and the causes of a short supply were, as stated, a slow decrease in the late flow, from deforestation on the one hand, and on the other a constantly growing demand for later water for the rapidly increasing acreage of alfalfa and crops other than grain. The cultivation of great areas of mesa lands, like that begun by the Union Colony at Greeley in 1870, was of course the greatest factor in calling attention to the short supply.

Up to the time of the passage of the law of 1879 many of the later users contended that the water must be pro rated in accordance with the old law of 1861, amended in 1870. This law provided that the county judge should appoint three commissioners, whose duty it was to "apportion in a just and equitable proportion a certain amount of said water upon certain or alternate weekly days to different localities." In 1879 the legislature passed the first bill intended to meet the conditions existing. Exclusive jurisdiction was by this law vested in the district court whose territory embraced the water district. "But when the water district extended into more than one county, the court of the county in which the first regular term after the 1st day of December of each year shall soonest occur shall be the proper court," and such court retained jurisdiction to final settlement. The district judge was required to appoint a referee to take testimony, who should issue a notice stating the time and place where he would hold court, notifying all interested parties to be present and to submit proofs of claims or present objections to the claims of others. The referee could call and examine witnesses, and he submitted his findings to the court for final adjudication. Those refusing to present their claims were barred as against those submitting proof. Appeal from the decree of the judge could be made within two years, and the court would thereupon order a rehearing.

Little was done under this law, many details of procedure being omitted. In 1881, therefore, the act was amended, making further provisions for settling and recording priorities of right, viz, a provision for petitioning the district court to proceed to an adjudication of rights, for the water commissioner to keep a record of decrees, and that the county clerk should record them; also for numbering the decrees, for keeping the testimony where it could be inspected by interested parties, for fixing the method of procedure in cases of appeals to the supreme court, which court could then render a decree, and providing that four years in place of two be allowed in which proceedings may be begun to set aside the decrees.

The present practice in obtaining title to water is to have the ditch or reservoir surveyed and platted, then either before or after construction statements are filed in the offices of the State engineer and county recorder. After completion of the works and after the water has been applied to the land a petition is presented to the district court asking that the rights be defined; after proper notice to all interested parties and due publication, the evidence is taken by the judge or a referee, and decree entered according to the findings. The water commissioner and other officials are notified by the clerk of the court, and a copy of the decree is furnished. Adverse claimants may, within four years, present their protest to the court, and the usual court procedure establishes the contested rights. The following circular, issued by the State engineer's office, gives the forms used at present for filing claims to ditch and reservoir rights, and is in accordance with the laws now in force:

[Circular.]

STATE ENGINEER'S OFFICE, *Denver, Colo.*

Instructions for preparing sworn statements and maps in the appropriation of water for ditches, canals, and reservoirs, and for the preparation of plans of specifications for dams.

RECORDING STATEMENTS OF CLAIMS TO WATER RIGHTS.

STATE OF COLORADO, *County of* ———, *ss:*

Statement of claim to water right.

Irrigation division No. —. Water district No. —.

The undersigned, ——— ———, owner— of the following-described ditch, in compliance with the requirements of general section No. 1720 of the general statutes of the State of Colorado, and the amendments thereto, —— hereby make this statement for filing in the proper offices:

1. The name— of the owner— of the said ditch, ——— ———, whose post-office address is ———, county of ———.

2. The name of the said ditch is the ——— ditch.

3. The head gate of the said ditch is located on the —— bank of ———, from which stream said ditch diverts its suppy of water, at a point whence the —— corner of section ——, in township ——, of range —— west, bears —— feet.

From the head gate the said ditch runs in a general —— direction, as shown on

the map hereto attached and made a part of this statement; which said map also shows the ownership of the lands over which said ditch passes, and distances of the ditch line from the Government corners.

4. The length of the said ditch is —— miles.

5. The width of the said ditch is —— feet on the bottom and —— feet at the high-water line.

6. The depth of said ditch is —— feet at high-water line.

7. The grade of said ditch is —— feet per mile.

8. The carrying capacity of the said ditch is —— cubic feet of water per second of time.

9. Work was commenced on the said ditch on the —— day of ———, A. D. 19—.

10. The —— enlargement of said ditch was commenced on the —— day of ———, A. D. 19—.

11. The said ditch, as enlarged, is —— feet wide on the bottom, —— feet wide at high-water mark, —— feet deep at high-water mark, and the increased capacity arising from such enlargement is —— cubic feet of water per second of time.

(Signed.)

Reservoir statements for filing should be as follows:

STATE OF COLORADO, *County of* ——, *ss:*

Statement of claim to water right.

Irrigation division No. —. Water district No. —.

The undersigned, ——— ———, owner— of the following-described reservoir, in compliance with the requirements of general section No. 1720 of the general statutes of the State of Colorado, and the amendments thereto, do— hereby make this statement for filing in the proper offices:

1. The name— of the owner— of said reservoir, ——— , whose post-office address is ——, county of ——.

2. The name of said reservoir is the ——— reservoir.

3. The said reservoir is situated on the —— ¼ of the —— ¼, the —— ¼ of the —— ¼, the —— ¼ of the —— ¼, and the —— ¼ of the —— ¼ of section ——, in township ——, of range ——, in —— county aforesaid.

The —— of said reservoir being at a point when the —— corner of said section —— bears —— feet.

4. The area of said reservoir at the high-water line is —— acres and at low-water line is —— acres. The depth of water that can be drawn off is —— feet, making the available capacity for storage —— cubic feet, for which claim is hereby made.

5. The said reservoir derives its supply of water from the —— through the —— ditch, the head gate of which is located at a point whence the —— corner section ——, in township ——, of range ——, bears ——, —— feet. Said ditch has a carrying capacity of —— cubic feet of water per second of time.

The head gate of the feeder from said —— ditch to the said reservoir is at a point whence the —— corner section ——, in township ——, of range ——, bears ——, —— feet.

6. Said feeder is —— feet wide on the bottom, —— feet wide at high-water mark; is —— feet deep, with a grade of —— feet per mile and a carrying capacity of —— cubic feet of water per second of time.

7. Work was commenced on said reservoir on the —— day of ——, A. D. 19—, and on the feeder above described, on the —— day of ——, A. D. 19—.

8. The outlet ditch from said reservoir is —— feet wide on the bottom, —— feet wide at high-water mark; is —— feet deep, has a grade of —— feet per mile and a carrying capacity of —— cubic feet of water per second of time.

9. Work was commenced on said outlet on the —— day of ——, A. D. 19—.

(Signed.)

LAWS.

The water laws of the State have been discussed heretofore in bulletins issued by the Department of Agriculture more fully than is here possible; therefore the briefest outlines and the statement of the fundamental principles only which underlie the law and are the basis of our court decisions are given.

In Bulletin No. 58, Office of Experiment Stations, United States Department of Agriculture, issued in 1899, the laws were given and discussed at some length, and in Bulletin No. 60, of the same office, issued in 1899, the methods and laws governing the acquiring of title to water were published.

The right of appropriation, as stated, is based upon the Territorial laws, the act of Congress in 1866, and the State constitution, which latter declares: "The water of every natural stream not heretofore appropriated is hereby declared to be the property of the public and is dedicated to the use of the people of the State, subject to appropriation."[a]

Theoretically, the fundamental principle of our laws, and one that should be the basis of all irrigation laws, is that the water is the property of the people, and the right to its use depends upon its being a beneficial application. It does not matter what a person's decree may be, nor what he may have diverted, nor for how many years, nor what his claims may be, he should have no right to water which he does not need and can not use beneficially.

The next question of importance is whether or not water attaches to the land. The decisions of the court, in the absence of any law on the subject, control in Colorado. Contrary to general belief, the State supreme court held that the water and land were not attached; and this decision was the basis of the greater part of litigation, permitting as it does the transfer of water and enlargement of ditches to the full amount of the decree.

The right of persons along the borders of a stream to an undiminished flow has been abrogated in Colorado, and by the decision of the State supreme court "the common-law doctrine of riparian rights is inapplicable to Colorado." The law abrogating riparian rights is slightly modified, however, by allowing such persons as have enjoyed the benefits of water from streams for meadow lands by the natural overflow, in case the flow is diminished to such an extent that they are denied the benefits of such overflow, to construct a ditch from the stream to irrigate the meadow; the priority to date from the time when the land was first used as a meadow.

Priority of appropriation shall give the better right; unappropriated waters are subject to appropriation for canal or reservoir purposes, and any excess above that needed for direct irrigation may be stored.

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[a] Constitution, Art. XVI, sec. 510.

Incorporated companies may obtain decrees and may collect fees as common carriers, and as long as there is water in the canal must permit persons under the canal to use the same upon the payment of the carrying charge. This charge may be regulated by the board of county commissioners.

When water is distributed to users or ditches for a length of time proportionate to their claims, usually the maximum quantity that can be used economically, the process is known as "prorating." In the distribution of water, while prorating is not sanctioned by law in filling ditches from the river, it is permissible in distributing to owners in common under one ditch; the point of difference being that in one case the dates of decrees are different, in the other they are identical.

The right to the use may be transferred from one individual to another, and a deed to the land does not carry the right to the water unless specifically mentioned. Water may be transferred from one ditch to another and its point of diversion changed up or down the stream. It may be transferred from one drainage to another; its place and character of use may be changed, providing always that the established rights of others in the waters are not interfered with.

The builders of ditches have the power to condemn a right of way. Ditches are not subject to taxes except when constructed for the purpose of deriving a revenue therefrom.

Domestic uses have no real preference over agricultural except that water used for agricultural purposes may be condemned when necessary for domestic uses. This right of condemnation alone distinguishes them.

Seepage and waste waters may be appropriated and are governed by the same laws as water from streams.

The laws passed by the general assemblies of 1899 and 1901 are quite important; they are interesting also as pointing out the difficulties to be overcome and as showing the effort toward more economical use of water. The laws of 1899 provided that filings shall be examined by the State engineer and a fee for the same collected. This is a step in the right direction; but the State engineer can not reject the filings, he having only power to return them and request a more accurate and complete statement. He does not examine into the merits of the claim that reservoirs covering more than 20 acres or having a dam more than 10 feet high shall be under the control of the State engineer, both during construction and afterwards. He may fix the height to which a reservoir may be filled at any time. This law provides penalties and methods of procedure against dams deemed unsafe, and upon complaint of three persons the State engineer must examine the dam complained of. The costs of the examination fall on the persons making the complaint if made on insufficient ground—a very wise provision, as it acts as a check on the ill-considered reports people are so

prone to make; at the same time the law stops the tendency of men in charge to overcrowd the capacity of the reservoir.

The most important law, however, and the one attracting the most attention during the legislative term of 1899 was the one providing for the transfer and exchange of water.[a] This law is given here in full:

SEC. 1. Every person desirous of changing the point of diversion of his right to use water from any of the streams of this State shall present his petition to the district court from which the original decree issued, praying such changes may be granted to him, and the practice and procedure on the hearing of such petition shall be the same as if said petition were for an original decree. The court shall require proof that all parties who may be affected by such change have been duly notified of the proceeding; and shall hear evidence to determine whether or not such change will injuriously affect the vested rights of others in and to the use of water; and if the said court shall find that such change will not injuriously affect the rights of others, a decree shall be entered allowing said party to make such change.

SEC. 2. Upon the granting of such decree as provided for in the first section hereof, the party desirous of making such change shall cause to be prepared two accurate maps showing the old and new ditches, the surrounding lands, and the lands of other owners in the vicinity, in the same manner as required in the case of original appropriations of water, and shall file one of said maps and a certified copy of the decree with the county clerk of the county in which the head gate of the ditch, as sought to be changed, is situate, and another copy of said map and decree shall be filed with the State engineer, whereupon said State engineer shall issue a notice to the water commissioner having jurisdiction over said ditch, notifying him of the change made, and thereupon said water commissioner shall allot the priority right to the use of water to the new ditch which formerly was allotted to the original ditch, and shall recognize such change in the distribution of water.

SEC. 3. It shall be lawful, however, for the owners of ditches and water rights taking water from the same stream to exchange with, and loan to, each other for a limited time the water to which each may be entitled, for the purpose of saving crops or of using the water in a more economical manner: *Provided*, That the owner or owners making such loan or exchange shall give notice in writing signed by all the owners participating in said loan or exchange stating that such loan or exchange has been made, and for what length of time the same shall continue, whereupon said water commissioner shall recognize the same in his distribution of water.

SEC. 4. In the opinion of the general assembly an emergency exists, therefore this act shall take effect and be in force from and after its passage.

Approved, April 6, 1899.

The first two sections of the bill are generally approved, as taking out of the hands of the irrigation officials the power to order a change from one ditch to another, and as rendering any surreptitious change invalid. Of course, the great good accomplished is that it gives notice to all who could be injuriously affected that they have the right to appear and object; and, too, after the order of change has been granted in accordance with law the decree under the change is not liable to be assailed, and so the title is as good and permanent as though no change had been made. Another good feature is that a map of the old and new ditches and the lands thereunder must be filed; this filing becomes a valuable document for reference to the

[a] Laws 1899, p. 235.

irrigation officials and to those looking up titles to water for lands in that vicinity, and amends in some degree the lack of such filings in the early days. The necessity for obtaining a transfer decree before the change is made makes it possible to ascertain many matters of fact, and so affirm or deny statements made for or against the transfer. The question of the capacity of the old ditch is not the least important of these, affecting the amount which in justice might be transferred. The old ditches could seldom carry their full decrees, and so a measurement on the ground during the existence of the old ditch is certainly necessary. In many of the old transfers, by the time a suit was brought to set it aside or limit it the old ditch had so filled up and changed that its original capacity could not be determined. The determination of seepage water, which contributed to fill the old ditch, can likewise be determined accurately only at the time of transfer, and not some years later.

The principal objection urged against these sections is that they are too severe in their requirements for notification and entail a considerable expense. This is probably true, but transfers are serious matters, and not to be lightly entered into, but after due consideration, soberly, and in the fear of litigation. There appears no way to secure perfect right of either original decree or of transfer excepting to make all persons who could possibly have a claim on the water parties to the suit, and the matter of cost is nothing compared with the feeling of perfect peace engendered by the knowledge of unassailable title.

It has recently been enunciated by one of the district judges that the above law simply states a method of procedure which was the only legal way of making a transfer before, and is only in accordance with the law passed in 1881 prescribing the procedure for obtaining decrees. It is a great pity that this fact has transpired only after twenty years of costly litigation, and that the above law was necessary to call the attention of the legal profession and of learned judges to these now obvious facts.

A valid objection against a law which puts obstacles in the way of transfer is that all such changes tend to more economical use of water, or to its application to more productive land, and should be encouraged. Any legitimate transfer has one of these for its object. The abandonment of the old bottom lands and the redemption of warm, productive mesas is of benefit to the community as a whole. The application of water to more productive land, producing as it does a greater return, enhances the value of the water, and the more valuable the water the more carefully and economically it is used, and the greater its duty. By transfer several ditches can be consolidated into one; the cost of repairs and maintenance diminished, as well as the loss by seepage and evaporation. This saving by lessening seepage and evaporation is more considerable than appears at first glance, for not only is the

exposed surface diminished, but as transfers are almost always upstream the waste encountered by traversing a broad, sandy river bed to the lower head gates is eliminated entirely.

Section 3 of the act quoted above was the most discussed and the most highly praised or bitterly condemned of any law ever passed relative to irrigation, and its praise or blame rested on whether the individual was benefited or conceived himself to have been hurt. That the law in its practical application both benefited and hurt irrigation there can be no doubt; but it was in the interpretation of the law by the different commissioners and superintendents that the benefit or harm lay. The section was intended to sanction the exchange and prorating of water in times of emergency and to enable a ditch of late priority to obtain water late in the irrigating season for the preservation of orchards and small fruits and for domestic use, where it would require only three or four days' run to give the orchards or other crops an irrigation that would probably last them the rest of the season. It was also deemed proper and desirable where a ditch had a small but early priority, not sufficient to reach the end of the ditch on account of loss by seepage and evaporation that it should be permitted to agree with another ditch in similar circumstances to loan its water for a short time to such other ditch, and in return should receive the water of that ditch for a like time, and each could with combined heads force the water to the end of the ditch.

The law sanctions the exchange of water between ditches and reservoirs. It is very often impracticable for a ditch company to have its reservoirs so located that the stored water is available for use on its land. If, however, it is allowable for it to give its stored water to a ditch lower on the stream and receive at its head gates water from the river on that ditch's priority, a distinct gain results. Also, reservoir construction is encouraged and no one is injured, as the amount of water diverted at the time of exchange is not increased.

The commissioners and the superintendent of one division gave the most liberal interpretation to the law. They decided that as the law read "the water commission shall recognize the same" (notice of agreement of exchange) in his distribution of water, they had no discretion in the matter, and as a consequence transfers were made whenever and however best suited the contracting parties. It is more than suspected that actual sales of water were made by some parties having old priorities. The effect of such a proceeding is readily seen; priorities were practically suspended and decrees nullified; ditch No. 1 "loaning" water it could not use to ditch No. 3 deprived ditch No. 2 of water which would otherwise have been in the river and available for the filling of decrees. Crops were not only "saved," as allowed by the law, but planted, grown, and matured on "borrowed" water. Under so liberal a ruling, the management of a ditch could deprive the

consumers thereunder of water they actually needed. They would probably not have the assurance to cause any loss of crops, but they could considerably inconvenience and embarrass the users and sell the surplus to some needy canal. For some unaccountable reason and contrary to all previous practice, the ditches injuriously affected accepted this interpretation and suffered in Spartan silence so far as appeal for redress to either the State engineer or the courts were concerned. In another division the superintendent assumed an exactly opposite position, and ordered his commissioners to recognize no notices of transfer. The courts have not been able to pass on the constitutionality of the act, and it seems that this superintendent was equally in error with the one already mentioned.[a] The three other superintendents who had occasion to pass upon the law agreed that in its workings it was of the greatest benefit in the saving of crops and in the economical use of water. As no complaints were made of the exchanges in these divisions, we may assume that the users were pleased with the section.

Some law is necessary, so long as human nature is as it is, to enable those in authority to prevent the selfish from playing the "dog in the manger." To be sure, there is a law prohibiting waste, but it is not to the public interest for a man to use water to irrigate stubble land to bring up wild oats, or to wet the land for the next season's plowing when an orchard, the result of years of labor, is in danger of being ruined; and if a man in a neighborly spirit sees fit to abandon his third crop of alfalfa and loan his water for the purpose of saving crops, it is public policy to allow him to do so. The law properly interpreted and executed can be of great benefit and at the same time not interfere with vested rights. If the conditions recited in the section are adhered to, and if the broad principle of noninterference with the rights of others is kept in mind, no one can object; to get any benefit, however, from the law one must be just and reasonable in determining the rights of others. Theoretical and inconsequent damage should not be allowed to prevent the good which might be done.

The condition specifically stated in the section that the loan is made for the purpose of saving crops should be rigidly adhered to. The loan is not for the purpose of making crops, but for saving those already practically matured. To be saved an article must necessarily be in existence. As already pointed out, the exchange may result in a great saving of water, and when a loan or exchange is made, if it is a loan or exchange contemplating a return in like amount, gifts and sales of water are excluded. Again, the loan is for a limited time. This clause is, I admit, indefinite, and might be expressed more clearly

[a] The supreme court of the State has recently upheld the constitutionality of the act. New Cache la Poudre Irrigating Company *v.* Water Supply and Storage Company, 68 Pac., 781.—Ed.

by saying for one irrigation; and such an interpretation of "a limited time" is very proper; anything less would be nothing; anything more would be precluded by the clause "for the purpose of saving crops." When more than one irrigation is needed to save a crop, then that crop is not sufficiently advanced to be considered as in existence, or rather to have value sufficient to justify the upsetting of the status of the river to save it.

It would not be wise to repeal the law, as was attempted during the last session of the legislature, but it should be so amended as to make it more definite in its phraseology; but any such law must of necessity depend for its beneficial application upon the good judgment of the water officials.

The laws passed by the legislature of 1901 were, one by Senator Clayton, providing penalties for not maintaining good head gates and rating flumes, the penalty being that the water could be shut out until the law was complied with. It also prohibits the storing of water when the same is required for direct irrigation. This section is hardly applicable as between reservoirs with rights senior to the ditches using the water direct. If the owners of a reservoir of old priority have enjoyed its use for years, it is unreasonable to suppose that a recent ditch can interfere with that use. The act further provides that reservoirs situated on the bed of a stream through which a natural flow passes must have a survey made and its contour lines run, and must place a gauge rod therein to mark the depth of water in the reservoir.

The second act provides that any interference with head gates or measuring boxes is a misdemeanor, "and that any person who shall be found using water taken through any such head gate so unlawfully interfered with shall prima facie be deemed guilty." This law makes it possible to convict water thieves without having to catch them in the act of tampering with the head gates. Heretofore convictions have been few, because it was often impossible to prove who individually committed the act of raising the head gate. In its operation it should be a good law.

The third law provides for the formation of irrigation districts, methods of holding elections, issuing bonds, etc. The law has had no test as yet, and no criticism of its effects, therefore, can be made.

LITIGATION.

On the Big Thompson nearly all the litigation has been by parties on the north side of the river against those on the south side. The Loudon and the Loveland and Greeley companies joined interests against the Handy and the Home Supply companies, the other and smaller ditches being drawn into the controversy.

In the descriptions of the ditches attention has been called to some

of the peculiarities of the decrees, and in the table below are summarized the findings and decrees. The wide divergence between the quantities of water granted and the capacities of the canals and needs of the land has been responsible for nearly all the litigation. The first table is a summary of the report of the referee appointed to take testimony and report findings upon which the court should render its decree. The second table is the decree of the court supposedly based on the report of the referee.

Claims presented to referee and his findings on which decree by the judge was rendered.

Name of ditch.	Width.		Length.	Depth.	Fall per mile.	No. of priority.	Amount decreed.	Amount claimed.	Under ditch.	Irrigated.
	Bottom.	Top.								
	Feet.	*Feet.*	*Miles.*	*Feet.*	*Feet.*		*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acres.*	*Acres.*
Big Thompson, No. 1[a]	10	14	8	3	7	1	96.50	96.50	2,640	2,500
Big Thompson and Manufacturing Co.'s Ditch	5	7	2.25	1	25	2	34.20	37.40	920	400
Do	6	8	4.5	2.5	25	4	37.10	44.90	1,320	1,000
Do	8	12	.....	2	25	12	65.47	90.86	2,180	1,500
Do	8	12	.....	3	25	24	9	(*b*)	2,180	1,500
Mariano[c]	4	5	1.5	0.2	8.92	3	38.41	3.12	.....	120
Farmers' Irrigating[d]	[e]15.1	.....	15	3.2	2.88	4	5.72	5.72	4,300	2,100
Do.[d]	[e]15.1	.....	15	3.2	2.88	17	2.60	2.86	4,300	2,100
Do.[d]	[e]15.1	.....	15	3.2	2.88	43	54.08	62.40	4,300	2,100
Big Thompson Irrigating[f]	8	14	3	2.5	10	5	78	75	1,000	1,000
Loveland and Greeley[g]	[e]24	31	2	2	6.7	6	18.56	18.56	3,600	195
Loveland and Greeley branch[h]	4	16	2.75	1	4.5	7	8.36	18.36	3,250	250
Do	8	12	3.5	2	2	13½	12.60	.....	690	690
Do.[i]	8	12	3.5	2	2	17	39.40	39.40	690	690
Loveland and Greeley[j]	8	12	3.75	2.5	4.5	21½	19.92	19.93	3,600	560
Loveland and Greeley branch[k]	10	15	2	2.5	2	23	35.50	35.50	1,400	1,400
Do.[l]	15	19	7	2	2	42	15.20	15.20	2,100	1,800
Loveland and Greeley	25	31	26.5	3	3	48	297.44	528	30,000	1,000
Big Thompson and Platte River	4.5	8.5	7	2	6.7	8	35	35	3,000	1,500
Do.[m]	9	14	7	2.5	6.7	31	86.18	86.18	3,000	2,000
Rist and Goss	3	5	1	7.5	5	9	6.41	10.50	400	43
Do.[n]	[e]6	.....	1	2.5	5	29	80.07	80.07	400	225
Hill and Brush	10	15	4.7	2.5	2.4	11	61.80	69	1,500	1,500
Loudon	4	5.5	3.7	1.5	5	18	40	40	13,103	.....
Do	12	18	19.5	3	5.5	38	154.30	158.80	13,103	.....
George Rist[o]	11	18	3.5	3.5	4.2	21	195	195	3,500	100
Do	11	18	8	3.5	4.2	21	195	195	3,500	2,400
Hillsboro	[e]16	.....	2.3	1.3	2.5	25	8.25	8.25	300	300
Do.[p]	[e]16.5	.....	12.3	2.7	3.2	40	99.45	100	6,000	1,800
Do	[e]18	.....	19.3	3	3.2	51	45.69	.....	6,000	3,000
Handy	7	15	21.5	2.5	4	39	31.20	520	10,000	1,000
Do	[e]12	.....	21.5	4	5.8	47½	141.23	.....	10,000	7,000
South Side[q]	7	9	9	2	4	47	50.30	49	1,500	600
Home Supply	15	23	26	4	3.2	50	278.84	299.50	15,000	11,520

[a] 0.026 cubic foot=1 inch.
[b] Full capacity.
[c] Not sufficient data to render a decree.
[d] All in one application.
[e] Average width.
[f] Capacity 103 cubic feet.
[g] Barnes Ditch.
[h] 7.8 feet recommended by referee.
[i] 12.6 recommended by referee—branch Loveland and Greeley.
[j] Barnes Ditch.
[k] 17.3 recommended by referee.
[l] 9.1 cubic feet recommended by referee.
[m] Capacity 78 cubic feet.
[n] Amount carried 4.7 cubic feet.
[o] Amount carried 124 cubic feet.
[p] Amount carried 74 feet.
[q] Amount carried 15.6 feet.

Statement of priorities of the ditches in water district No. 4 from the decrees of the district court.

Name of ditch, canal, or reservoir.	Streams from which water is taken.	Date of appropriation.	Amount decreed.	Sum decreed to each ditch, canal, or reservoir.	Water previously appropriated in district.	Order of priority in district.
			Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	
Big Thompson Ditch	Big Thompson	Nov. 10, 1861	96.50	.....	3.12	1
Big Thompson and Manufacturing Co.'s Ditch.	.....do	Apr. 1, 1863	34.02	.....	99.62	2
Mariano Ditch	.....do	May 1, 1863	3.12	.....	133.64	3
Big Thompson and Manufacturing Co.'s Ditch, first enlargement.	.....do	May 1, 1864	37.01	71.03	136.76	4
Farmers' Irrigating Canal	.....do	.....do	5.72	.....	173.77	5
Big Thompson Irrigating Ditch.	.....do	Feb. 25, 1865	78	.....	179.49	6
Loveland and Greeley Canal.	.....do	Oct. 20, 1865	18.56	.....	257.49	7
Loveland and Greeley Canal (branch).	.....do	Nov. 1, 1865	8.36	26.92	276.05	8
Big Thompson and Platte River Ditch.	.....do	Nov. 18, 1865	35	.....	284.41	9
Rist and Goss Ditch	.....do	Mar. 20, 1866	6.41	.....	319.41	10
Hill and Brush Ditch	.....do	June 30, 1866	61.80	.....	332.06	12
Big Thompson and Manufacturing Co.'s Ditch, second enlargement.	.....do	Mar. 1, 1867	65.47	136.50	393.86	13
Loveland and Greeley Canal, first enlargement.	.....do	June 1, 1867	12.06	38.98	478.83	15
Farmers' Irrigating Canal, first enlargement.	.....do	June 1, 1868	2.60	8.32	492.06	17
Loveland and Greeley Canal, second enlargement.	.....do	Oct. 20, 1870	39.04	78.02	526.17	21
Loudon Irrigating Canal	.....do	Oct. 1, 1871	40	.....	565.21	22
Big Thompson and Manufacturing Co.'s Ditch, third enlargement.	.....do	May 1, 1872	9.75	146.25	608.67	24
George Rist Ditch	.....do	May 1, 1873	195	.....	618.42	25
Loveland and Greeley Canal, third enlargement.	.....do	June 23, 1873	19.93	97.95	813.42	26
Loveland and Greeley Canal, fourth enlargement.	.....do	Oct. 25, 1873	35.50	133.45	833.35	27
Kirchner Ditch	Buckhorn Creek	June 1, 1874	6.81	.....	868.85	28
Perkins Ditch	.....do	June 15, 1874	2.60	.....	875.66	29
Hillsboro Ditch	Big Thompson	Oct. 15, 1874	8.25	.....	878.26	30
Rist and Goss Ditch	.....do	Apr. 15, 1875	80.07	86.48	904.55	33
Big Thompson and Platte River Ditch, first enlargement.	.....do	May 15, 1876	86.18	121.18	1,048.95	37
Loudon Irrigating Canal, first enlargement.	.....do	Nov. 1, 1877	154.30	194.30	1,190.25	40
Handy Ditch	.....do	Feb. 28, 1878	31.20	.....	1,344.55	41
Hillsboro Ditch, first enlargement.	.....do	Apr. 15, 1878	99.46	107.71	1,375.75	42
Farmers' Irrigating Canal, second enlargement.	.....do	Aug. 1, 1878	54.08	62.40	1,475.21	43
Loveland and Greeley Canal, fifth enlargement.	.....do	Nov. 1, 1878	15.20	148.65	1,529.29	44
South Side Ditch	.....do	Nov. 7, 1880	50.30	.....	1,586.28	49
Handy Ditch, first enlargement.	.....do	Dec. 15, 1880	141.23	172.43	1,636.58	50
Loveland and Greeley Canal, sixth enlargement.	.....do	Apr. 1, 1881	297.44	446.09	1,777.81	51
Perkins Ditch, second enlargement.	Buckhorn	June 9, 1881	4.47	7.57	2,075.25	52
Home Supply Ditch	Big Thompson	July 15, 1881	278.84	.....	2,079.72	53
Hillsboro Ditch, second enlargement.	.....do	Oct. 6, 1881	45.69	153.40	2,358.56	54
Loudon Irrigating Canal, second enlargement.	.....do	Sept. 17, 1883	123.48	317.78	2,404.25	55

NOTE.—The rights to water from Little Thompson Creek, which were included in the original decree, are omitted in this table.

Statement of priorities of reservoirs in water district No. 4, from the decrees of the district court.

Name of reservoir.	Stream from which water is taken.	Date of appropriation.	Amount of appropriation.	Order of priority in district.
			Cubic feet per second.	
Rist	Big Thompson	Sept. 15, 1874	5,210,865	1
Mariano	do	Oct. 1, 1875	180,865,000	2
Bennetts	St. Vrain and Little Thompson	Feb. 25, 1880	1,267,800	3
Big Thompson	Big Thompson	May 18, 1881	44,000,000	4
Farwell	do	Aug. 31, 1881	400,000,000	5
Loudon	do	Feb. 24, 1883	50,000,000	6

Examination will show there was apparently no rule adopted by the judge or referee for estimating the amount of water the ditches carried or the amount of water necessary to irrigate an acre of land. The judge has in some cases followed the referee's recommendation and in others ignored it. The referee, in turn, generally accepted as correct the statements of the claimants, but in others he did not, though there appears to be no reason for the distinctions. In some cases he allowed an amount sufficient to irrigate all the land under the ditch; in others he confined the amount to the land actually irrigated. In some he allowed water for land which by an extension and enlargement of the ditch might be irrigated. In one case at least he allowed water to only the land actually irrigated, ignoring the fact that the ditch for nearly its entire length could carry a volume sufficient for all the land under it, that work was rapidly prosecuted, and that this land was irrigated at the earliest practicable date. In this case he did not take into consideration the extent and difficulty of construction, but divided the decree into several parts, each of date when water was actually applied without reference to the time of beginning construction. In another case, contrary to the statements made in the application and request for two decrees of different dates, he granted one decree aggregating in amount the total of the two and of date of the older.

FIRST SERIES OF CONTESTS.

The Handy Ditch, intended and located to cover nearly all the land on the south side, is by the decree granted a flow of 31.2 cubic feet per second to irrigate 15,000 acres of land. The priority of the balance, 141.23 cubic feet per second, was dated three years later, as the company had not been able to begin and complete a ditch capable of carrying the total amount through its entire proposed length the first year after work was begun. This action allowed 260 cubic feet per second for various ditches and enlargements to intervene between the two priorities.

The officers of the Handy Ditch, ignorant that the referee had taken it upon himself to divide their decree without notice to them, and,

being unaffected thereby on account of the abundance of water in the river and the small amount withdrawn by the older priorities, allowed nearly the full four years within which an appeal from the decree could be made to lapse. The decree was granted May 28, 1883, and not until the fall of 1886 did the water commissioner find it necessary to turn water from the Handy Ditch to fill decrees between the two dates of the decrees of the Handy Ditch. Investigation disclosed the true state of things, and suit was immediately brought by the Handy Company to set aside the decrees; brought, however, in the district court of Larimer County. Thus in its effort to save its right, the Handy Company precipitated, in the spring of 1887, a legal contest not yet ended. The case was entitled "The Loudon Irrigation and Canal Co. et al. *v.* The Handy Ditch Co. et al." (22 Colo., p. 102.)

The suit was originally brought in the district court of Larimer County and in effect was an attempt to set aside the decrees for the entire district. The Handy Company, believing that the decrees of the older ditches were excessive and that they were entitled to have their entire decree of one date—the date of the beginning of construction—instead of two dates, sought relief by the above action.

The defendants (The Loudon et al.) denied the jurisdiction of the Larimer County court and alleged insufficient cause of action, which latter contention the court upheld, but claimed jurisdiction. Upon appeal to the supreme court, that tribunal reversed the lower court in the matter of jurisdiction, sustaining the law of 1879, section 19, which gave exclusive jurisdiction to the court where the decrees were first rendered, which in the case of district No. 4 was the Boulder County district court. The case does not touch the point whether one district can reopen the decrees of another district after four years have elapsed. It simply says that any action growing out of the decrees must be tried before the court which rendered the decrees and within four years of the date of such decrees.

The effect of the decision is to establish more firmly the validity of a decree. If at any time after four years an adjudication could be opened up, and especially if before another court, the adjudication would be of slight avail, and title to water could not be finally and firmly settled. When it is remembered that months and years of labor have been spent in arriving at a decision, it would be folly to allow the work to be a subject of question for all time. It would be eminently proper to allow a certain time to elapse to test the practical workings of the decrees before making them unassailable; but, very properly, there should come a time when decrees are established beyond the possibility of question.

Upon being remanded, some new points were brought out, and so the case reached the supreme court a second time under the title of "The Handy Ditch Co. *v.* The South Side Ditch Co. et. al." (26 Colo., p. 333.)

In this second trial before the Larimer County court the Handy Company still contended that that court had jurisdiction and showed that, acting under the law of 1879, proceedings were begun in that court by the appointment of a referee and the taking of considerable evidence prior to the institution of proceedings under the law of 1881 by the Boulder County court. On this point, however, the Larimer County court held, in view of the decision of the supreme court in the previous case, that the Handy Company, being a party to the proceedings before the court of Boulder County and having acquiesced in the same, were bound by its decrees. The supreme court affirmed the decision of the lower court, and the four years having elapsed within which to begin proceedings before the Boulder court, this phase of the case ended.

SECOND SERIES OF CONTESTS.

In the meantime, however, the Handy Company, anticipating the adverse decision, sought to remedy their misfortune by taking advantage of the condition of the decrees and to turn to their benefit what had been an injustice to them. They therefore purchased an old ditch and the land under it, abandoned the irrigation of the land, and sought to transfer the water. This proceeding inaugurated the second series of contests, the interests of the contestants, however, being the reverse of that in the first series. It now became vital for the Handy Company to uphold and maintain the justice and validity of the decrees and for the north side ditches practically to break and set aside the decrees.

The Handy Company, in view of the court decisions in the first cases, had rather the better of the situation, while its adversaries were in something of a dilemma from this cause. They, however, avoided the real issue by admitting the correctness and validity of the decrees, but contended that immediately after and ever since the decree was issued the use of the water had been abandoned in whole or in part; that the area irrigated was small, and on account of increasing seepage had constantly grown less since the time of the decree. Much evidence was introduced by both sides to show the amount of water required for such lands. The evidence introduced by the Handy Company was very similar to that given before the referee when the decrees were rendered, not only in regard to the ditch in question, but for the very ditches constituting the opposition.

The evidence of the opposition was in direct and glaring contrast to that given by them in obtaining decrees, and the only reason it did not react on themselves was that since the adjudication they had so enlarged their canals and so extended the use of the water that the full amount decreed was in time used. On the other hand, there was no enlargement or extended use of the ditch in question.

The case coming on appeal by both the defendants and plaintiffs to the supreme court is known as "The Handy Ditch Co. *v.* The Loudon Irrigating Canal Co." (62 Pacific Reporter). The facts in the case were: The Handy Ditch Company purchased the Big Thompson Irrigating Ditch and the lands under it, some 800 acres, abandoned the latter, and applied to the superintendent of irrigation to transfer the water to the Handy Ditch some 10 miles above the head gate of the old ditch. The amount of the decree was 78 cubic feet per second, dated February 25, 1865, being the fifth decree in the district, and commonly known as "No. 5 ditch." The superintendent allowed but 40 cubic feet per second to be transferred, as he contended that the old ditch could not carry much more than one-half of its decree. On appeal to the State engineer he caused the ditch to be measured and levels run, from which the estimated capacity was shown to be from 100 to 150 cubic feet per second. He therefore ordered the full amount to be transferred. In the meantime, however, the north-side ditches had brought suit, as stated, in the Larimer County court, which court held that the evidence showed that not more than 20 of the 78 cubic feet per second had been used of late years. It excluded evidence which tended to show that much or all of the 20 cubic feet per second used was seepage and return water which entered the river between the old and new points of diversion, upholding the argument of the Handy Company that the decree was not for water which might, at some date subsequent to the date of the decree, have found its way back to the river, but for that which constituted part of the original supply in the stream.

In its appeal to the supreme court the Handy Company urged that the finding was in error, in that the evidence did not warrant the reduction from 78 to 20 cubic feet per second, and that the court erred in not admitting evidence as to the size and capacity of the ditch. The defendants appealed on the ground that evidence was excluded which would have shown that whatever water had been used by "No. 5" ditch was water which entered the river as seepage below the head gate of the Handy Ditch, and if any water was transferred that it would be withdrawn from the original supply in the stream, and the use of which they heretofore had enjoyed.

The supreme court affirmed the decision of the lower court so far as it related to the amount of water used by the "No. 5" ditch, but remanded the case with instructions that if a new trial was had it should embrace only the question of whether the 20 feet found to have been used by "No. 5" ditch was in whole or in part seepage water and not available for the filling of decrees of the Loudon or other older ditches.

The decision of the supreme court will probably stand, namely, that 20 of the 78 cubic feet decreed to the "No. 5" ditch will be transferred to the Handy. With the final determination of this suit the litigation will end, though in the district court at present are some six suits in

which the north side ditches are seeking to prevent the transfer of water from the Big Thompson Ditch and Manufacturing Company's Ditch and the Big Thompson No. 1 ditch to the Handy, Home Supply, and Hillsboro ditches.

The suits are simply a continuation of the efforts of the south-side ditches to overcome the disastrous effects of the decrees which gave excessive amounts to the old ditches, allowing enlargement and increased use to an extent which has seriously affected the water available to fill their priorities.

OTHER LITIGATION.

NEW LOVELAND AND GREELEY LAND AND IRRIGATION COMPANY *v.* HOME SUPPLY COMPANY.

[62 Pacific Reporter.]

Both parties to this suit own large and valuable reservoirs under their respective canals—Lake Loveland under the Loveland and Greeley Canal and the Mariano and Lone Tree reservoirs under the Home Supply. The action was brought in the district court of Boulder County to establish the relative right of priority of these reservoirs.

The Loveland and Greeley Ditch priorities as decreed are prior to those of the Home Supply. The relative dates of construction of the reservoirs, however, are reversed, the Home Supply reservoirs being in 1882 and 1889 and the Loveland Lake in 1893, each exercising due diligence after commencement of work on the reservoirs in prosecuting the same to completion.

The Loveland and Greeley Company claimed the right under its ditch decree to divert the amount of its decree at any time and for any purpose which was more effective or economical; that is, to have the right to store water during the nonirrigating season on its ditch decree, the reservoir being a part of its system and its construction contemplated at the time the several priorities were obtained, though it did not begin construction for some ten years after the decree was rendered fixing the ditch priority and some twenty-eight years after the date of its first priority.

The Home Supply Company claimed that its reservoirs were constructed and in operation ten and four years prior to the construction of Lake Loveland; that the right of storage attaches when the actual work of construction of the reservoir is begun and prosecuted with due diligence, and not when the feeder to the reservoir was begun, unless the two are closely connected in point of time, in intention and actual construction.

The court held that the mere intention is of itself insufficient to give a vested right, but must be manifested by the completion of the general plan and a beneficial use within a reasonable time.

The Loveland and Greeley Company relied, however, mainly on its decree fixing the priority of right for agricultural purposes, which "fairly interpreted" would give it the right to store water in reservoirs it might thereafter construct. The court says, "There are two sufficient replies to this contention. First, it was not within the jurisdiction of the court in the proceedings leading up to the decree to make an absolute and unconditional decree of priority for a reservoir not then begun or constructed, and in the second place the decree itself does not purport to do so," but expressly excludes appliances not then in existence. In such cases as this it would seem unjust that a late ditch which had provided itself with the means of supplying its deficient early rights should, after the enjoyment of that means for a number of years, be subject to an old priority seeking to enlarge its diversion of water from the stream by means of storage.

LOWER LATHAM DITCH COMPANY *v.* LOUDON IRRIGATING CANAL COMPANY ET AL.

[Pacific Reporter 60, p. 629.]

This suit was to test the relative rights of priority in two districts dependent on each other: Whether ditches in district No. 4, from the Big Thompson River, were or should be subject to the rights of prior appropriation below on the Platte River in district No. 2.

The users on the Big Thompson obtained an injunction restraining the water commissioner from complying with the order of his superior, the superintendent, to close out ditches on the Big Thompson in order to supply such priorities on the Platte River as were earlier than those on the Big Thompson. The water commissioner notified the plaintiffs of the action and forwarded to them his notifications, etc., expecting them to defend their rights. They, however, allowed the case to go by default, but subsequently brought the present action to compel a recognition of their older rights.

The defendants pleaded that while the plaintiffs were not parties to the injunction suit, nevertheless they had notice, and so were bound by the decree. Also that for a number of years the ditches on the Big Thompson had used the water now asked for by the ditches on the Platte, who, with a knowledge of this, had nevertheless allowed the practice to continue without protest, permitting improvements to be made in district No. 4 under the belief that there was water in sufficient quantity and not subject to the priorities below, and though in need of the water to fill their priorities the ditches of district No. 2 had allowed their rights to lapse. They set forth also that even should the water be turned out of the Big Thompson ditches to fill those of the Platte, it would do so slowly and after great loss in volume.

The district court of Larimer County sustained these positions, which,

however, the supreme court reversed, holding that the plaintiffs were not parties to the injunction suit, though having knowledge of the same, and that "if a failure of one diverting water from a stream to protest every time a shortage in his supply is occasioned by another withdrawing water to which he is not entitled is to be construed as acquiescence amounting to abandonment priorities would be of little value." Also the fact that a considerable loss in volume would occur through evaporation and percolation was not sufficient reason for depriving the lower ditches of their rights of priority.

This case confirms the practice and belief that rights on tributaries and on the main stream, though in different districts of the same division, are subject to prior rights of all other ditches of the division.

COMMENTS.

In looking over the water conditions in Colorado, examining the causes of the legal contests and difficulties of administration, no one thing seems to be entirely responsible, each succeeding cause or error depending on what had preceded and on what followed to produce the full measure of difficulties. Each mistake seemingly had a chance of correction, but, instead of a correction, only additional errors were made.

First, the absence of records, filings of statements in the early days was a bad beginning, second, the laws of 1879 and 1881 relative to decrees fell short of their intention to supply the deficiency in records; third, the adjudication of water rights failed to eliminate the errors made possible by the incompleteness of the laws of 1879 and 1881 and added others; fourth, subsequent litigation perpetuated and exaggerated these errors.

The law relative to filings passed in 1881 has a few faults—namely, that it came almost twenty years too late to do much good, and there is no provision for an official examination and acceptance of the filings, and that the courts have held it to be unconstitutional in that noncompliance therewith can not deprive an appropriator of his constitutional right to the use of water.

Filings are of little value except as evidence of time when the claim was made and of intention. Filed in the county recorder's office, they are not indexed with reference to the land covered, and nowhere appear in the abstracts of the land. There is no method in use for abstracting water rights, and it is impossible to determine who the owners are or to what land the water is applied. This looseness of the record of ownership of decrees, as well as undecreed ditches, has led to much litigation. Not only is the irrigator constantly threatened by the dangers incident to water supply and control, but is surrounded by an atmosphere of doubt as to the exact status of his title and the rights upon which the success or failure of his efforts depend.

There being no official examination and acceptance of these claims filed, what is the result of the uncontrolled and indiscriminate filing? District No. 4 has suffered little from filings as compared with other districts since adjudications were had. On page 47 is a summary of the filings made since 1887, which shows claim for nearly three times the average flow of the stream for ditches alone, and for reservoirs of nearly 7,500,000,000 cubic feet—more than the entire flow in the river for an average year. In addition to this, it must be remembered that the amount of water actually decreed to ditches only by the courts (see table of decrees, page 64), and which are prior to these claims, is nearly 200 cubic feet per second in excess of the maximum recorded flow of the river during the last twelve years and exceeds the average recorded flow for the month of June by 1,657 cubic feet per second. Now, add to this reservoir decrees to the extent of 15,000 acre-feet. This tendency to make excessive filings and claims was encouraged by the condition of the decrees, they being, as indicated, far in excess of the amount available, while, in point of fact, after the old ditches were filled there remained in the stream and subject to appropriation considerable unused water.

It was very unwise in the beginning not to have some control and restriction of these filings. One man files on "all the surplus and unappropriated water" without doing any work other than a rough survey, and, too, after the waters have been filed on to ten times the discharge of the stream. Another files on "50,000 cubic feet per second," when the stream, in its wildest moments of storm, melting snow, and cloudburst, never carried one-tenth that amount; and there those absurd "filings" stand like specters, intimidating bona fide settlers and legitimate corporate enterprise and casting doubt upon the title to water of existing ditches.

The law of 1881 was intended to determine the rights to water of different claimants and to fix those rights; to bring to a stop, as it were, the old order of things and to start a new, with the past definitely settled and the future controlled. The records to this time depended on the memory of the "oldest inhabitant," who was passing away. The difficulties of a just determination were great, but their importance was greater, though hardly appreciated by either the claimants or the courts. Each appropriator presented his claim, and his neighbors and friends corroborated his statements. Almost never was anyone's claim questioned or examined by others interested. The only question gone into with any thoroughness was the date of priority; the size, length, capacity, and location were mere statements. The acreage to be irrigated, while generally given, was guessed at, as was the amount necessary to an acre. The location of the canal and the ownership were in no more definite form. Especially noticeable was the absence of any State control or any effort on the part of the State to protect the interests of those who were to come after. A "cubic

foot of water per second" had no meaning to some; others maintained that 12 "inches"[a] was a foot; others still that 144 or 1,728 was correct. It would appear from the results that the majority favored the 12 inches to a foot idea, resulting in decrees three times what was intended.

It is strange that the judge or referee, who presumably knew of the conflict of opinion and of the wide range of statements relative to what was necessary to irrigate an acre of land and what constituted an "inch," did not avail himself of the services of a competent engineer, who would report on each ditch, classify the land under each, estimate the acreage, measure the canal, and ascertain its capacity and the amount it probably used. The expense would have been much less than the witness fees or the time value of the gratuitous witnesses.

Had we at that time had a State engineer who, without bias or prejudice, employing the same methods of measurements and standards of classification, was authorized to make reports, the judge would have had reliable, uniform data on which to base his decrees; instead of such information he relied on the statements of interested parties, who were ignorant alike of standards or methods of measurement. During the last year a man who has been irrigating for at least thirty years demanded in all seriousness and good faith 2,000 inches of water for a 320-acre farm. About 200 inches were turned into his ditch and he reported that he was getting his 2,000 inches all right. He is a type of the witnesses testifying before the referee—honest and with the best of intentions. The result of all this was, naturally, excessive decrees and indefinite and conflicting terms, as in the decree previously given. The peculiarities of the decrees in district No. 4 have been discussed, but all the above reasons and those previously mentioned do not explain, nor can they excuse all the mistakes made. No man, no matter how good a judge or attorney, is competent to render decrees unless he has had practical experience in the handling and distribution of water, and for this reason it seems necessary either to remove the settling of priorities from the judiciary or to supply them with such expert aid as is necessary.

A board consisting of men trained in the service who recognize its needs, the difficulties and dangers likely to arise, and who can and will make examination on the ground to settle disputed facts, seems far superior to a judge who has had at most little practical experience with water, who is accustomed to handling civil cases with rules of procedure scarcely applicable to irrigation cases, and who in the press of other work can not take the time necessary to become personally familiar with the case on the ground as well as in the court room. To

[a] In Colorado an "inch" is the volume which will pass through an orifice 1 inch square under a pressure of 5 inches, measured from the top of an orifice, and varies somewhat with the number of "inches" sought to be measured; 38.4 inches is the accepted equivalent of a cubic foot per second, however.

go on adding reasons for such a change, in view of the condition of the decrees already rendered by the courts, is entirely unnecessary. If the customs and laws are so firmly grounded as to preclude the possibility of the change indicated, a law requiring the State engineer to examine and make report on the ditches of a district before decrees are entered would meet most requirements. In the old districts, however, where the decrees have become fixed, the State engineer should be required to examine each ditch, reservoir, and decree, and upon his report to the district judge, after proper hearing, excess decrees should be declared abandoned.

Enlargement is productive of more evil than transfers. Transfers are open, subject to examination and question. Enlargement is a slow, insiduous, intangible process of taking more and more water from the river and of depriving later appropriators of benefits which they have before enjoyed. The simple process of cleaning a ditch, if well and thoroughly done, may be made in a few years to double the capacity. An examination and record of the present ditch capacities would prevent much of this and declared abandonment, resulting in practically a new set of decrees, would stop it altogether.

The decrees all contain one element so indefinite that one is at a loss how at this time to apply a remedy, though in future decrees this might be more specifically stated—that is the time element. A decree purports to establish the maximum amount of water that can be diverted at any time. It is left to conjecture, however, for what length of time the water is so run. Under the conditions existing at the time appropriations were made for the early ditches, and extending even to the time of the decree, the water was used quite differently from what it is at present. The crops were all early maturing and required little late water. Now, however, both early and late crops are raised, the result being that instead of having little use for water after July it is now demanded for August and September as well. Formerly water was run on the land perhaps one week in the month; now with larger ditches, larger and more diversified crops, it is run every day in the month. This, then, is an increase in the length of the season and of use from an intermittent to a continuous flow, with the result of a largely increased acreage irrigated and actual volume diverted though the number of cubic feet per second may be no greater.

This enlarged use is made possible by the segregation of the land and water under the rulings of courts and brings up a consideration of the fourth item in the summary on page 64.

Numerous cases have been tried in the State in which the right to transfer water has been confirmed. With the conditions of excess decrees, it is to be expected that the excess, when water becomes valuable, will, if possible, be used. The water becomes an article of sale and purchase, and, while as stated in the section on laws, transfer,

extension, and enlargement are benefits to the community as a whole, confiscation of the property of the individual results for the benefit in particular of the holders of an old decree and of the community in general. With decrees more definite as to length of time and use and limited in quantity to the needs of the land irrigated, transfers would be a benefit as they would encourage consolidation of ditches and economy of use. Conditional decrees could be granted dependent on the completion of extensive works and the actual reclamation of the land within a reasonable period.

In the administration of the irrigation department, one must contend with the acts of those who believe themselves to have been wronged and who by force seek to maintain their rights, but discretionary power of the officers has been so curtailed and limited that they are often forced to do things against both their judgment and inclination. Every irrigation official should be clothed with more discretionary power, and the decisions of the State engineer should stand until the courts decide adversely, instead of being overruled by injunction. An official who is sworn and under bonds to do his duty is enjoined from doing this duty. The presumption of impartiality is as strong in him as in a judge; his ability to judge of a case is superior; he is familiar with the law and customs; he knows, by long exercise of his duties, the priorities, the needs, and the rights of the ditches; he knows almost by instinct the effect of certain actions and decisions; he has knowledge which neither laws nor decrees, nor books, nor records can give; he has seen the effects actually worked out on the ground; he is vitally interested in the good conduct of his office, and he is subject to immediate removal in consequence of any misconduct. It is simply absurd that the court should presume without investigation, and in ex parte proceedings to set aside his rulings.

CONCLUSION.

In the foregoing pages, as far as possible, facts as ascertained from personal observation have been given, and criticism of doubtful points has been avoided. An attempt has been made to give an outline and something of a history and the sequence of events which led up to the legal contests, said by some to be only the beginning, but which are more probably the beginning of the end. Other nations have had nearly the same questions and difficulties to meet, and found the solution of their troubles and worked out their own salvation. With them it required centuries for final settlement. In the United States the progress made in Colorado in one short generation gives no reason for discouragement. An efficient system of administration has been worked out, and a system of adjudication has been adopted, which needs only a better knowledge of the requirements of irrigation practice to make it satisfactory.

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